THURBER ENGINEERING LTD.

DRAFT
FOUNDATION INVESTIGATION AND DESIGN REPORT
WIDENING OF EASTBOUND TRANSFER
BETWEEN COLLECTOR AND EXPRESS
HIGHWAY 401 BASKETWEAVE
MISSISSAUGA, ONTARIO
G.W.P. 2147-10-00, CONTRACT 2

GEOCRES NO.

Report

to

AECOM

Date: December 1, 2016
File: 12669

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the design and construction of the proposed widening of the eastbound transfer between the eastbound collector and the eastbound express of Highway 401 east of Etobicoke Creek, Mississauga, Ontario. Thurber was retained by AECOM to carry out the foundation investigation at this site on behalf of the Ministry of Transportation Ontario (MTO) under Assignment No. 2012-E-0036.

The purpose of the field investigation was to explore the subsurface conditions at the site and provide a borehole locations plan and soil strata drawing with stratigraphic profiles, records of boreholes, laboratory test results, and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained during the course of the present investigation.

2 SITE AND PROJECT DESCRIPTION

The site is located on Highway 401 approximately 650 m east of Etobicoke Creek, Mississauga, Ontario. Based on the available drawings provided by AECOM dated August 29, 2016, this project includes widening of the transfer connecting the eastbound collector and the eastbound

express (basketweave) between approximate Station 10+060 and Station 10+490. Embankment widening will require fill placement on the existing fill slopes. The earthwork required to widen the transfer lanes will take place on the south side of the embankment between Stations 10+060 and 10+200. Between Stations 10+200 and 10+270, both sides of the embankment will be widened. Between Stations 10+270 and 10+490, the widening will occur on the north side of the embankment. In addition, a temporary retaining wall will be constructed over a 100 m long segment to support the added fill material north of the eastbound collector to express transfer between Stations 10+330 and 10+430.

The area to the north of this section of the Highway 401 corridor is occupied by Pearson Airport lands. The area to the south of the basketweave is largely of commercial and light industrial usage.

From published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the site lies within the physiographic region known as South Slope. The South Slope generally consists of sandy materials (derived from glacial tills) overlying glacial tills. The soil deposit is underlain at relatively shallow depths by grey shale bedrock of the Georgian Bay Formation.

3 INVESTIGATION PROCEDURES

The site investigation for this project was carried out between September 26 and October 4, 2016 during which time a total of nine (9) boreholes denoted as Boreholes BW 16-01 to BW 16-09 were advanced to depths ranging from 6.2 m to 13.7 m.

Boreholes BW16-01 to BW 16-04 were advanced between approximate Stations 10+100 and 10+200 on the south side of the existing eastbound transfer; whereas, Boreholes BW 16-05 to BW 16-09 were advanced between Stations 10+240 and 10+430 on the north side of the existing eastbound transfer. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing provided in Appendix C. Borehole details are provided in Table 3.1 below.

Table 3.1 – Borehole Details

Borehole Number	Approximate Station (m)	Approximate Ground Surface Elevation (m)	Borehole Termination Depth (m)	Borehole Termination Elevation (m)
BW 16-01	10+110	161.6	8.1	153.5
BW 16-02	10+130	160.7	7.7	153.0
BW 16-03	10+170	164.3	13.7	150.6
BW 16-04	10+200	159.6	7.8	151.8
BW 16-05	10+240	160.1	7.7	152.4
BW 16-06	10+290	159.0	6.2	152.8
BW 16-07	10+330	158.7	7.7	151.0
BW 16-08	10+380	164.1	10.7	153.4
BW 16-09	10+430	159.8	7.7	152.1

A track-mounted drill rig was used throughout the field investigation. The boreholes were advanced using hollow stem augers to reach the target depths. In all boreholes, soil samples were obtained at selected depth intervals with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT).

Groundwater conditions were observed in the open boreholes throughout the drilling operations. Standpipe piezometers were installed in Boreholes BW 16-01, BW 16-04, BW 16-05, and BW 16-07 to permit monitoring of the groundwater levels at the site. Each piezometer consisted of a 25 mm diameter PVC pipe with a slotted screen sealed at a selected depth within the borehole. The boreholes in which no piezometer was installed were backfilled in general accordance with Ontario Regulation 903. Piezometer installation and borehole completion details are summarized in Table 3.2 below.

Table 3.2 – Piezometer and Borehole Completion Details

Borehole Number	Piezometer Tip Depth / Elevation (m)	Completion Details
BW 16-01	7.4 / 154.2	Backfilled with filter sand from 8.1 m to 5.4 m, then bentonite holeplug from 5.4m to 4.4 m, then bentonite and auger cuttings to surface.
BW 16-02	None installed	Backfilled with bentonite holeplug and auger cuttings to surface.

Borehole Number	Piezometer Tip Depth / Elevation (m)	Completion Details
BW 16-03	None installed	Backfilled with bentonite holeplug and auger cuttings to 0.1 m below ground surface, and then asphalt to surface.
BW 16-04	7.6 / 152.0	Backfilled with filter sand from 7.8 m to 5.4 m, then bentonite holeplug from 5.4 m to 4.4 m, then bentonite and auger cuttings to surface.
BW 16-05	7.6 / 152.5	Backfilled with filter sand from 7.7 m to 5.4 m, then bentonite holeplug from 5.4 m to 4.6 m, then bentonite and auger cuttings to surface.
BW 16-06	None installed	Backfilled with bentonite holeplug and auger cuttings to surface.
BW 16-07	7.7 / 151.0	Backfilled with filter sand from 7.7 m to 5.3 m, then bentonite holeplug from 5.3 m to 2.7 m, then bentonite and auger cuttings to surface.
BW 16-08	None installed	Backfilled with bentonite holeplug and auger cuttings to 0.2 m below ground surface, and then asphalt to surface.
BW 16-09	None installed	Backfilled with bentonite holeplug and auger cuttings to 0.2 m below ground surface, and then asphalt to surface.

The field work was supervised on a full time basis by a member of Thurber's technical staff who marked/staked the boreholes in the field, arranged for the clearance of buried utilities, directed the drilling, sampling and in-situ testing operations, logged the boreholes and processed the recovered soil and rock samples for transport to Thurber's laboratory for further examination and testing.

4 LABORATORY TESTING

All recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to grain size distribution analysis (hydrometer and/or sieve analysis) and Atterberg Limits testing, where appropriate. Laboratory testing results are summarized on the Record of Borehole sheets included in Appendix A and are

presented on the figures included in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix A and on the Borehole Location and Soil Strata Drawings in Appendix C. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the site conditions. It should be recognized and expected that soil conditions may vary between and beyond borehole locations.

In general, the subsurface stratigraphy encountered in the boreholes consists of either surficial topsoil or pavement structure (asphalt underlain by sand base) overlying silty clay embankment fill. The fill layer is underlain by a silty clay till deposit which overlies weathered grey shale bedrock. The groundwater level varied from 2.4 m to 7.4 m below the existing ground surface. A description of each major stratigraphic layer is provided below.

5.1 Topsoil

A layer of surficial topsoil with a thickness ranging from 50 mm to 160 mm was encountered in some boreholes. Boreholes BW 16-03, BW 16-08, and BW 16-09 were drilled through paved areas.

5.2 Pavement Structure

Pavement structure consisting of asphalt overlying granular fill materials was encountered in Boreholes BW 16-03, BW 16-08, and BW 16-09. The thickness of the asphalt ranged between 150mm and 175 mm. The granular base consisted of sand, some gravel to gravelly sand, and was found to range between 0.6 m and 0.8 m in thickness in Boreholes BW 16-03 and BW 16-08, while the granular thickness in Borehole BW 16-09 was 1.2 m. The measured water content of the granular fill ranged from 2 to 5%.

The results of a grain size distribution analysis carried out on a sample of gravelly sand are presented on the Record of Borehole Sheets included in Appendix A and on Figure B1 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	23
Sand	29
Silt	30
Clay	18

5.3 Silty Sand to Sand Fill

A fill layer of silty sand to sand, trace to some gravel and trace to some clay was encountered below the topsoil or the pavement structure in Boreholes BW 16-01, BW 16-02, BW 16-05, and BW 16-09. This layer has a thickness varying between 0.6 m and 1.4 m. The base elevation of this fill layer varied from Elevations 157.7 to 160.2 m.

SPT 'N' values recorded in this fill ranged from 8 to 15 blows per 0.3 m penetration in Boreholes BW 16-01 and BW 16-05, respectively, indicating a loose to compact condition. Higher SPT "N" values of 56 blows per 0.3 m penetration to greater than 62 blows for less than 0.3 m of penetration were measured in Boreholes BW 16-02 and BW 16-09, indicating a dense to very dense condition. Measured moisture contents within this layer varied between 5% and 10%.

The results of grain size distribution analyses carried out on one sample of the silty sand fill are presented on the Record of Borehole Sheets included in Appendix A and on Figure B2 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	7
Sand	48
Silt	28
Clay	17

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5.4 Silty Clay Fill

The majority of the embankment fill consists of silty clay with some sand and trace gravel was encountered in all boreholes except Borehole BW 16-09, either under the sand and silt fill, topsoil, or the pavement structure. The thickness of the silty clay fill layer ranged from 1.6 m (in Borehole BW 16-05) to 4.2 m (in Borehole BW 16-01). The base elevation of this fill varied between Elevations 156.0 m and 160.3 m.

SPT 'N' values recorded in the silty clay fill typically ranged from 8 to 45 blows per 0.3 m penetration indicating stiff to hard consistency. An occasional 'N' value of 69 blows for less than 0.3 m penetration indicated the presence of cobbles or boulders. The exception was in Borehole BW 16-01 at an approximate depth of 3 m, and in Borehole BW 16-04 under the topsoil where SPT 'N' values of 5 to 7 were measured indicating a firm consistency. The measured moisture contents within this cohesive fill varied between 10% and 22%.

A layer of sandy silt fill with trace to some clay and trace gravel and occasional cobbles was encountered underneath the silty clay fill in Boreholes BW 16-03 and BW 16-04. The thickness of this fill layer was 1.6 m in Borehole BW 16-03, and 0.9 m in Borehole BW 16-04. The moisture content of this layer was in the range of 7% to 8%. The SPT 'N' values recorded in this fill layer ranged from 14 blows per 0.3 m penetration in Borehole BW 16-03, indicating a compact condition, to 72 blows per 0.3 m penetration indicating a very dense condition.

The results of grain size distribution analyses and Atterberg Limits testing carried out on selected samples of the silty clay fill are presented on the Record of Borehole Sheets included in Appendix A and on Figures B3, B4 and B6 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	22 to 28
Silt	36 to 47
Clay	30 to 39

The results of Atterberg Limits testing are summarized below:

Index Property	Percentage (%)
Plasticity Index	10 to 20
Liquid Limit	24 to 36

The results of the Atterberg Limits testing indicate the layer is of low to intermediate plasticity with a group symbol of CL to CI.

5.5 Silty Clay Till

A till deposit consisting of silty clay, with sand and trace gravel was found underlying the fill in Boreholes BW 16-01, BW 16-02, BW 16-03, and BW 16-05. Where fully penetrated, the thickness of this cohesive till deposit ranged from 2.7 m to 4.7 m. The base elevation of this layer ranged from 152.8 m to 155.1 m. Borehole BW 16-01 was terminated with the silty clay till at 8.1 m depth (Elevation 155.5 m).

SPT 'N' values recorded in this till deposit typically ranged from 21 blows per 0.3 m penetration to greater than 100 blows for less than 0.3 m of penetration, indicating a very stiff to hard consistency. The higher 'N' values and observations during drilling inferred the possible presence of cobbles within the till. Measured moisture contents within the till layer varied between 8% and 18%.

The results of grain size distribution analyses and Atterberg Limits testing carried out on selected samples of the silty clay till are presented on the Record of Borehole Sheets included in Appendix A and on Figures B5 and B7 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 8
Sand	31 to 38
Silt	36 to 40
Clay	19 to 29

The results of Atterberg Limits testing are summarized below:

Index Property	Percentage (%)
Plasticity Index	14 to 23
Liquid Limit	29 o 41

The results of the Atterberg Limits testing indicate the layer is of low to intermediate plasticity with a group symbol CL to CI.

Glacial tills inherently contain cobbles and boulders.

5.6 Sandy Silt Till

A sandy silt till with trace gravel and trace clay was encountered underlying the silty clay till in Boreholes BW 16-02 and BW 16-03. Both of these boreholes were terminated in this till at 7.7 m and 13.7 m depths (Elevations 153.0 m to 150.6 m).

SPT 'N' values recorded in this layer was greater than 50 blows for less than 0.3 m of penetration indicating a very dense condition. Measured moisture contents within this layer was 8% to 10%.

5.7 Sand to Sand and Gravel

Layers of sand to sand and gravel, some silt and clay were encountered underlying the fill or till in Boreholes BW 16-04, BW 16-06, and BW 16-08, and interlayered with the silty clay till in Boreholes BW 16-03. The thickness of this layer ranged from 0.5 m to 2.1 m with base elevations varying between 153.5 m to 157.5 m.

Occasional cobbles, limestone, and weathered shale fragments were encountered within these soils in Boreholes BW 16-04 and BW 16-06.

SPT 'N' values recorded in these soils were typically greater than 50 blows for less than 0.3 m of penetration indicating a very dense condition. Measured moisture contents within these soils varied between 3% and 6%.

5.8 Shale Bedrock

The above soil layers are underlain by grey shale bedrock in Boreholes BW 16-04, BW 16-05, BW 16-06, BW 16-07, BW 16-08 and BW 16-09. The bedrock was typically weathered within the

augered zone. The top elevation of the shale varied between 153.5 m to 157.7 m as shown in Table 5.1 below. Occasional hard limestone interbeds was observed within the weathered shale in Boreholes BW 16-04, BW 16-06, and BW 16-09. The shale encountered in the boreholes is described as fine grained, thinly bedded and contains limestone interbeds.

Within the augered portion of the shale, the SPT N-values obtained in the shale bedrock were typically greater than 100 blows for less than 0.3 m penetration. Moisture contents in the SPT weathered shale samples ranged from 2% to 8%.

Table 5.1 – Depths and Elevations of Top of Shale

Borehole Number	Top of Weathered Shale	
	Depth (m)	Elevation (m)
BW 16-01	Not encountered	Not encountered
BW 16-02	Not encountered	Not encountered
BW 16-03	Not encountered	Not encountered
BW 16-04	6.1	153.5
BW 16-05	6.1	154.0
BW 16-06	2.4	156.6
BW 16-07	2.3	156.4
BW 16-08	6.6	157.5
BW 16-09	2.1	157.7

5.9 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. Standpipe piezometers were installed in Boreholes BW 16-01, BW 16-04, BW 16-05, and BW 16-07 to monitor the groundwater level at the site. The groundwater levels measured in the open boreholes and in the piezometers are summarized in Table 5.2 below.

Table 5.2 – Groundwater Levels and Observations

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
BW 16-01	November 07, 2016	7.0	154.6	Piezometer
BW 16-02	September 26, 2016	dry	-	Open hole
BW 16-03	September 27, 2016	dry	-	Open hole
BW 16-04	November 07, 2016	6.0	153.6	Piezometer
BW 16-05	November 07, 2016	7.4	152.7	Piezometer
BW 16-06	October 03, 2016	dry	-	Open hole
BW 16-07	October 04, 2016 November 07, 2016	2.4 3.1	156.3 155.6	Open hole Piezometer
BW 16-08	September 29, 2016	dry	-	Open hole
BW 16-09	October 04, 2016	dry	-	Open hole

The groundwater levels above are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

6 MISCELLANEOUS

Thurber marked and/or staked the borehole locations in the field and obtained buried utility clearances prior to drilling. The northing and easting co-ordinates and elevations of the boreholes have been provided by AECOM.

Geotechnical laboratory testing was carried out at Thurber's MTO approved high complexity Toronto area laboratory.

Altech Drilling Ltd. supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation.

The field investigation was supervised on a full time basis by a member of Thurber's technical staff. Compilation of data and preparation of the report was carried out by Messrs. Mohamad Hosney, P.Eng. and Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., MTO designated principal contact.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report provides interpretation of the geotechnical data in the factual report and presents geotechnical recommendations to assist the design team in the design of the proposed widening of the Highway 401 eastbound transfer located east of Etobicoke Creek in the City of Mississauga, Ontario.

This foundation design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Based on the available cross sections and a General Arrangement (GA) drawing dated September 2016 provided by AECOM, this project involves widening of the eastbound transfer connecting the eastbound collector and the eastbound express (basketweave) between approximate Stations 10+060 and 10+490. The side slope of the existing embankments at the

basketweave is approximately 2H : 1V and the new fill will be up to 3 m in height above the slopes. There is no grade raise proposed for the highway.

The earthwork required to widen the transfer lanes will take place on the south side of the embankment between Stations 10+060 and 10+200. Between Stations 10+200 and 10+270, both sides of the embankment will be widened. Between Stations 10+270 and 10+490, the widening will occur on the north side of the embankment. In addition, a temporary retaining wall will be constructed over a 100 m long segment to support the added fill material north of the eastbound collector to express transfer between Stations 10+330 and 10+430. Based on information provided by AECOM, the wall will be in operation for about two months after which it will be removed and/or decommissioned.

8 EMBANKMENT WIDENING

New fill will be placed to widen the collector and express lanes within the basketweave. Provided that the new fill is placed as recommended below with a 2H : 1V inclination or flatter to match the existing slope configurations, the fill embankments at the basketweave will remain stable.

Between Stations 10+330 and 10+430, the proposed widening will consist of a temporary retaining wall to be constructed over a 100 m long segment to support the new fill to the east of the existing basketweave structure. Based on the site conditions and project requirements, this wall may consist of soldier pile and wood lagging or steel interlocking sheetpiles that can also be used as roadway protection (Section 11). Global stability of this temporary wall is addressed in the following Section 10.

Prior to fill placement, the subgrade must be adequately prepared to receive the fill. Within widening areas, all vegetation, topsoil, organics, soft/loosened or wet soils should be sub-excavated. All subgrade should be inspected and approved prior to placing fill. In areas where new fill is to be placed on existing fill, the existing fill surface should be benched in accordance with OPSD 208.01.

All widening fill must be constructed with adequate quality control in accordance with OPSS.PROV 206 and OPSS.PROV 501 requirements. It is recommended that OPSS.PROV.1010 Granular A, Granular B Type II or Type I, or Select Subgrade Material (SSM) be used as new fill. Consideration may also be given to using inorganic earth fill which, however, carries a higher potential for larger settlement due to fill compression.

Vegetation cover should be established on all exposed earth slopes for protection against surficial erosion. Reference should be made to OPSS.PROV 804.

9 RETAINING WALL BACKFILL AND LATERAL PRESSURES

The backfill to the temporary retaining wall should be in accordance with OPSS 902. Any backfill to the wall should consist of Granular A or Granular B Type II material meeting the requirements of OPSS.PROV 1010.

Earth pressures acting on the retaining wall may be assumed to be triangular and to be governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but are generally given by the expression:

$$p_h = K(\gamma h + q)$$

where: p_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see Table 9.1)

γ = unit weight of retained soil (see Table 9.1)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa).

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill for Granular A or Granular B Type II. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS.PROV 501.

Earth pressure coefficients for backfill to the retaining wall are dependent on the material used as backfill. Typical values are shown in Table 9.1.

Table 9.1 – Geotechnical Parameters of the Fill Materials

Wall Condition	Earth Pressure Coefficients (K)			
	OPSS Granular A and Granular B Type II $\phi = 35°, \gamma = 22.8$ kN/m^3		OPSS Granular B Type I $\phi = 32°, \gamma = 21.2$ kN/m^3	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement towards soil mass)	3.7	-	3.3	-

If the support system allows yielding of the wall (unrestrained system), active horizontal earth pressure may be used in the geotechnical design of the structure. If the support system does not allow yielding (restrained system), at-rest horizontal earth pressures should be used.

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall.

The factors in Table 8.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC 2014.

It is recommended that perforated sub-drains and weep holes be installed, where applicable, to provide positive drainage of the granular backfill behind the retaining walls. Reference should be made to OPSD 3102.100.

10 EMBANKMENT STABILITY ANALYSIS

Based on the embankment configurations provided by AECOM, limit equilibrium stability analyses were carried out for representative temporary and permanent cases. The stability analyses were

carried out using the commercially available slope stability program GEO-SLOPE and employing the Morgenstern-Price method of slices for limit equilibrium.

As per MTO practice, a minimum Factor of Safety (F.S.) of 1.3 is acceptable for maintaining global stability for a typical highway embankment.

10.1 Widening with Sloped Fill

The geotechnical parameters used in the stability analyses were determined from the in-situ testing conducted during the field investigation and/or estimated from soil index correlations.

All stability analyses were carried out under static conditions. Fill consisting of OPSS Granular B Type I material was assumed to be used to widen the transfer. A surcharge load of 12 kPa has been used in the analyses to simulate traffic loading. It is noted that the groundwater level has been assumed to be at the toe level of the side slopes. These parameters and the results of the stability analyses are shown on the figures in Appendix D. A summary of the stability analyses results are provided in Table 10.1 below:

Table 10.1 – Factor of Safety of Basketweave Embankment Slopes Stations 10+170 and 10+290

Station	Reference Borehole	Estimated Factor of safety				Figure
		Undrained Conditions		Drained Conditions		
		Current Conditions	After Widening	Current Conditions	After Widening	
10+170	BW 16-02 BW 16-03	2.2	1.3	1.3	1.3	D1 to D4
10+290	BW 16-06 BW 16-08	2.9	2.6	1.8	1.5	D5 to D8

The results of the slope stability analyses indicate that the Factors of Safety acceptance criteria outlined above are generally satisfied for the cases analysed.

10.2 Widening with Temporary Retaining Wall

For analysing global stability of the section where a temporary wall is to be used to retain the widening fill, a continuous wall such as a sheet pile wall installed into the top of shale, or a soldier pile and lagging wall with closely spaced piles, has been assumed. Geotechnical parameters similar to those discussed above have been used.

The results of the stability analyses are included in Appendix D. A summary of the stability analysis results is provided in Table 10.2 below:

Table 10.2 – Factor of Safety of Embankment Slopes with Wall
Station 10+340

Station	Reference Borehole	Estimated Factor of safety				Figure
		Undrained Conditions		Drained Conditions		
		Current Conditions	After Widening	Current Conditions	After Widening	
10+340	BW 16-07 and BW 16-08	2.7	3.3	2.0	3.0	D9 to D12

The results of the slope stability analyses indicate that the Factors of Safety are greater than 1.5 for the cases analysed.

It is noted that a discontinuous system of soldier piles and lagging with typical pile spacings will result in a global Factor of Safety of less than 1.1. In order for a soldier pile and lagging wall to be suitable for use as a temporary wall to retain the Highway 401 embankment, the piles will have to be spaced more closely than those used in typical shoring walls.

10.3 Settlement

Placement of the new fill will result in elastic compression of the silty clay fill and the over-consolidated silty clay till. To assess ground settlement in response to new fill placement, settlement analyses were carried out using commercially available computer programs. The results indicate that the estimated settlement is in the order of 15 to 25 mm and is expected to occur as the fill is placed. It is anticipated that post construction settlement should be negligible.

11 ROADWAY PROTECTION

The temporary retaining wall discussed above may be considered as a roadway protection system. Roadway protection may also be required elsewhere across the site. An item titled "Protection System" as per OPSS.PROV 539 should be included in the contract documents. It is recommended that Performance Level 1b as per Clause 539.04.01.01 be assigned for the temporary retaining wall which is to be used for retention of the Highway 401 embankment. Performance Level 2 may be assigned elsewhere. Proposed alignments of the roadway protection should be specified on the contract drawings.

The design of roadway protection should be the responsibility of the Contractor. For the temporary retaining wall, a continuous interlocking sheetpile system or a soldier pile and lagging system with closely spaced piles should be considered. It is anticipated that both the sheetpiles and the soldier piles will need to be extended through the existing silty clay embankment fill to reach the weathered shale to provide the required toe resistance. Pre-augering will be required to socket the soldier piles or the sheetpiles into the weathered shale.

It is important to note that the temporary retaining wall between Stations 10+330 and 10+430 is to retain widening fill on which there will be heavy Highway 401 traffic. A Performance Level 1b is therefore specified to minimize ground movements behind the wall. It is anticipated that the wall system may be stiffened by cross bracings, where applicable.

A sheet pile wall may be designed using the parameters given below:

Soil Bulk Unit Weight	γ	=	22 kN/m^3
Coefficient of Active Pressure	K_a	=	0.33 (fills)
Coefficient of Passive Pressure	K_p	=	3.0 (fills)
		=	4.2 (weathered shale)

It is recommended that lateral earth pressures acting on the wall be computed in accordance with the CHBDC 2014. The surcharge should include soil loadings above the top of the wall and other loadings including traffic loading adjacent to the wall. The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the roadway protection system.

The designer of the roadway protection system should check whether the depth of the wall is sufficient to provide base fixity.

All roadway protection systems should be designed by a Professional Engineer experienced in such designs.

12 ADJACENT STRUCTURES AND BURIED UTILITIES

Buried utilities might be present in the retaining wall construction area and the proposed embankment widening areas. It is recommended that the exact locations and elevations of these utilities be established by the designer, and compared with the extent of the potential work zones related to the widening activities. If necessary, relocation of and/or special protective measures for affected utilities may be required.

In addition, placement of new fill adjacent to the existing Highway 401 eastbound lanes will induce foundation settlement that could result in pavement distress on the travelled lanes of the highway. Should this occur, remedial measures including temporarily re-paving the affected areas may be required.

It buried utilities are present in the vicinity of the new fill and retaining wall, it is recommended that the following be carried out prior to the commencement of construction:

- Carry out pre-construction condition survey including documentation of any existing distress associated with the existing utilities. Any distress should be reported to and discussed with the structure/utility owner.

Potential impact of fill placement and temporary retaining wall construction on the existing pavement surface of Highway 401 should be closely monitored.

- Daily visual inspection of the pavement surface must be carried out in the vicinity of the fill placement and wall construction. If cracks form in the pavement or settlement is observed to occur, these matters must immediately be brought to the attention of the Contract Administrator for determining as to whether remedial action is required. Such action may include temporarily re-paving the affected areas.
- Implement a survey monitoring program to include ground settlement monitoring during installation of roadway protection/temporary retaining wall. The ground adjacent to the retained fills behind the temporary wall should be monitored for potential movement. This requirement will be addressed in an NSSP related to the design and installation of the temporary retaining wall.

13 CONSTRUCTION CONCERNS

During construction, the Contract Administrator should employ experienced foundation/geotechnical staff to observe construction activities. The following aspects should be considered:

- Horizontal deformation of the temporary wall can affect the integrity of the adjacent pavement structure including asphalt cracking. The wall should be sufficiently rigid such that the horizontal deformation would not exceed 10 mm (Performance Level 1).
- The fill and silty clay till may contain cobbles and boulders.
- The forward and side embankment slopes should be inspected after construction for surficial disturbance. Where necessary, remedial measures such as re-vegetation and/or placement of gravel sheeting may be required.

14 CLOSURE

Engineering analysis and preparation of this foundation design report was carried out by Messrs. Mohamad Hosney, P.Eng. and Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Contact for MTO foundation projects.

Thurber Engineering Ltd.

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Principal, Designated MTO Contact

THURBER

Appendix A

Record of Borehole Sheets

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BW 16-01 1 OF 1 METRIC

GWP# 2147-10-00 LOCATION HWY 401 EBL Basketweave Structure N 4 835 276.5 E 295 405.3 ORIGINATED BY ES

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.09.26 - 2016.09.26 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
161.6	GROUND SURFACE										
0.0	**TOPSOIL:** (50mm)										
0.0	**SAND**, some gravel, trace clay Compact Brown Moist (FILL)		1	SS	15		161		○		
160.9											
0.7	Silty **SAND**, some clay, trace gravel Loose Brown Moist (FILL)		2	SS	8				○		7 48 28 17
160.2							160				
1.4	Silty **CLAY**, some sand, trace gravel Firm to Stiff Brown Moist (FILL)		3	SS	8				○		
			4	SS	9		159		○		0 27 40 33
			5	SS	5				○		
							158				
			6	SS	12		157		○		
156.0											
5.6	Silty **CLAY**, with sand, trace gravel Very Stiff to Hard Brown Moist (TILL)		7	SS	22		156		○		
							155				
			8	SS	83		154		○		8 31 40 21
153.5											
8.1	END OF BOREHOLE AT 8.1m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2016.11.07 7.0 154.6										

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BW 16-02 1 OF 1 METRIC

GWP# 2147-10-00 LOCATION HWY 401 EBL Basketweave Structure N 4 835 299.1 E 295 433.2 ORIGINATED BY ES

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.09.26 - 2016.09.26 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
160.7	GROUND SURFACE										
0.0	**TOPSOIL:** (60mm)		1	SS	62/						
0.1	**SAND**, some silt, trace gravel, trace roots Very Dense Brown Moist (FILL)				0.175		160				
160.0											
0.7	Silty **CLAY**, some sand, trace gravel Stiff Brown Moist (FILL)		2	SS	14						
			3	SS	13		159				
	Trace roots Dark Brown		4	SS	9						0 23 47 30
			5	SS	13		158				
156.4											
4.3	Silty **CLAY**, with sand, trace gravel Very Stiff to Hard Brown Moist (TILL)		6	SS	29		157				
							156				7 38 36 19
			7	SS	50/						
153.7					0.100		155				
7.0	Sandy **SILT**, some clay, trace gravel Very Dense Grey Dry						154				
153.0	(TILL)		8	SS	100/		153				
7.7	END OF BOREHOLE AT 7.7m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.				0.125						

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\overset{20}{15\ 10\ 5}$ (%) STRAIN AT FAILURE

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Ontario

THURBER

RECORD OF BOREHOLE No BW 16-03 1 OF 2 METRIC

GWP# 2147-10-00 LOCATION HWY 401 EBL Basketweave Structure N 4 835 313.6 E 295 430.3 ORIGINATED BY ES

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.09.27 - 2016.09.27 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
164.3	GROUND SURFACE										
0.0	**ASPHALT:** (150mm)										
0.2	**SAND**, some gravel Compact Brown Moist		1	GS			164				
163.3	(FILL)		1	SS	11						
1.0	Silty **CLAY**, some sand, trace gravel Stiff to Very Stiff Brown Moist (FILL)		2	SS	16		163				
			3	SS	15		162				
	Trace rootlets Grey		4	SS	13		161				0 22 39 39
160.3											
4.0	Sandy **SILT**, some clay, trace gravel Compact Brown Moist (FILL)		5	SS	14		160				
158.7							159				
5.6	Silty **CLAY**, some sand, trace gravel Very Stiff to Hard Brown Moist (TILL)		6	SS	25		158				
			7	SS	50/ 0.050		157				3 35 39 23
155.1							156				
9.2	**SAND**, some silt, some gravel, occasional cobbles Very Dense Grey Moist		8	SS	100/ 0.250		155				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BW 16-03 2 OF 2 METRIC

GWP# 2147-10-00 LOCATION HWY 401 EBL Basketweave Structure N 4 835 313.6 E 295 430.3 ORIGINATED BY ES

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.09.27 - 2016.09.27 CHECKED BY MH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
	Continued From Previous Page										
153.9							154				
10.4	Silty **CLAY**, some sand, trace gravel, occasional cobbles Hard Brown Moist (TILL)		9	SS	100/ 0.100				○		
152.8							153				
11.5	Sandy **SILT**, trace gravel Very Dense Brown Moist (TILL)		10	SS	100/ 0.125		152		○		
150.6							151				
13.7	END OF BOREHOLE AT 13.7m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.1m, THEN ASPHALT TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \quad 5}$ (%) STRAIN AT FAILURE
$\frac{}{10}$

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THURBER

RECORD OF BOREHOLE No BW 16-04 1 OF 1 METRIC

GWP# 2147-10-00 LOCATION HWY 401 EBL Basketweave Structure N 4 835 331.2 E 295 473.8 ORIGINATED BY ES

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.09.27 - 2016.09.27 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
159.6	GROUND SURFACE						
0.0	**TOPSOIL:** (75mm)						
0.1	Silty **CLAY**, some sand, trace gravel Firm to Hard Brown Moist (FILL) Trace rootlets		1	SS	7		159
			2	SS	10		
			3	SS	22		158
			4	SS	42		157
156.5							
3.1	Sandy **SILT**, trace clay, trace gravel, occasional cobbles Very Dense Brown Moist (FILL)		5	SS	72		156
155.6							
4.0	**SAND**, some silt, occasional limestone and shale fragments Very Dense Grey Moist		6	SS	50/ 0.075		155
							154
153.5							
6.1	**SHALE**, weathered, occasional inferred limestone Grey		7	SS	100/ 0.050		153
							152
151.8			8	SS	100/ 0.175		
7.8	END OF BOREHOLE AT 7.8m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2016.11.07 6.0 153.6						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)

GR	SA	SI	CL
0	25	45	30

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

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THURBER

RECORD OF BOREHOLE No BW 16-05 1 OF 1 METRIC

GWP# 2147-10-00 LOCATION HWY 401 EBL Basketweave Structure N 4 835 388.9 E 295 474.0 ORIGINATED BY ES

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.10.03 - 2016.10.03 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
160.1	GROUND SURFACE										
0.0 / 0.1	**TOPSOIL:** (75mm)						160				
	Silty **SAND**, some clay, trace gravel, trace rootlets Compact Brown Moist (FILL)		1	SS	14				○		
159.4 / 0.7	Silty **CLAY**, some sand, trace gravel, trace roots Very Stiff Brown Moist (FILL)		2	SS	21		159		○		0 26 38 36
			3	SS	28				○		
157.8 / 2.3	Silty **CLAY**, with sand, trace gravel Very Stiff to Hard Brown Moist (TILL)		4	SS	21		158		○		0 31 40 29
			5	SS	50/ 0.125		157		○		
	Occasional cobbles		6	SS	50/ 0.050		156				
154.0 / 6.1	**SHALE**, weathered Grey		7	SS	50/ 0.125		155				
152.4			8	SS	50/		154		○		
7.7	END OF BOREHOLE AT 7.7m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2016.11.07 7.4 152.7				0.100		153		○		

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

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THURBER

RECORD OF BOREHOLE No BW 16-06 1 OF 1 METRIC

GWP# 2147-10-00 LOCATION HWY 401 EBL Basketweave Structure N 4 835 422.1 E 295 507.3 ORIGINATED BY ES

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.10.03 - 2016.10.03 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
159.0	GROUND SURFACE										
0.0	**TOPSOIL:** (50mm)										
0.0	Silty **CLAY**, some sand, trace gravel Stiff Brown Moist (FILL)		1	SS	10						
			2	SS	12		158				
157.1			3	SS	69/ 0.175						
1.9	**SAND** and **GRAVEL**, possible cobbles Very Dense		4	SS	50/		157				
156.6											
2.4	**SHALE**, weathered Grey				0.025						
			5	SS	83/ 0.225		156				
	Occasional limestone		6	SS	50/ 0.150		155				
							154				
152.8			7	SS	50/		153				
6.2	END OF BOREHOLE AT 6.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.				0.150						

$+^3$, $\times^3$: Numbers refer to Sensitivity

20
15 5
10
(%) STRAIN AT FAILURE

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Ontario

THURBER

RECORD OF BOREHOLE No BW 16-07 1 OF 1 METRIC

GWP# 2147-10-00 LOCATION HWY 401 EBL Basketweave Structure N 4 835 458.8 E 295 551.6 ORIGINATED BY ES

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.10.03 - 2016.10.04 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
158.7	GROUND SURFACE										
0.0	**TOPSOIL:** (160mm)										
0.2	Silty **CLAY**, with sand, trace gravel Stiff to Hard Brown Moist (FILL) Trace organics, trace rootlets		1	SS	10		158				
			2	SS	45						0 28 36 36
			3	SS	40		157				
156.4											
2.3	**SHALE**, weathered Grey		4	SS	50/0.125		156				
			5	SS	50/0.125		155				
			6	SS	100/0.125		154				
			7	SS	100/0.125		153				
							152				
151.0			8	SS	100/0.125		151				
7.7	END OF BOREHOLE AT 7.7m. WATER LEVEL AT 2.4m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2016.11.07 3.1 155.6										

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

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Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BW 16-08 1 OF 2 METRIC

GWP# 2147-10-00 LOCATION HWY 401 EBL Basketweave Structure N 4 835 484.9 E 295 609.9 ORIGINATED BY ES

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.09.29 - 2016.09.29 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
164.1	GROUND SURFACE						164				
0.0	**ASPHALT:** (175mm)										
0.2	**SAND**, some gravel Brown Moist		1	GS					○		
163.3	(FILL)						163				
0.8	Silty **CLAY**, with sand, trace gravel Stiff to Very Stiff Brown Moist (FILL)		1	SS	12				○		
			2	SS	14		162		○		
			3	SS	17				○		
			4	SS	26		161		○		
160.1											
4.0	Silty **CLAY**, with sand, trace gravel Hard Brown Moist (TILL)		5	SS	33		160		○		4 31 39 26
	Possible cobbles						159				
158.5											
5.6	**SAND** and **GRAVEL** Very Dense Grey Moist		6	SS	50/ 0.125		158		○		Resistance to augering from 6.1m to 6.6m
157.5											
6.6	**SHALE**, weathered Grey		7	SS	50/ 0.150		157		○		
							156				
			8	SS	50/ 0.075		155		○		

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BW 16-08 2 OF 2 METRIC

GWP# 2147-10-00 LOCATION HWY 401 EBL Basketweave Structure N 4 835 484.9 E 295 609.9 ORIGINATED BY ES

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.09.29 - 2016.09.29 CHECKED BY MH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
							154				
153.4			9	SS	50/				○		
10.7	END OF BOREHOLE AT 10.7m. BOREHOLE DRY UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.2m, THEN ASPHALT TO SURFACE.				0.075						

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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THURBER

RECORD OF BOREHOLE No BW 16-09 1 OF 1 METRIC

GWP# 2147-10-00 LOCATION HWY 401 EBL Basketweave Structure N 4 835 518.9 E 295 625.3 ORIGINATED BY ES

HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.10.04 - 2016.10.04 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
159.8	GROUND SURFACE										
0.0	**ASPHALT:** (160mm)										
0.2	Gravelly **SAND**, with silt, some clay Dense Brown Moist (FILL)		1	GS					○		23 29 30 18
			1	SS	43		159		○		
158.4											
1.4	**SAND**, some gravel, trace clay, occasional shale fragments Very Dense Brown Moist (FILL)		2	SS	56		158		○		
157.7											
2.1	**SHALE**, weathered Grey		3	SS	50/0.150		157		○		
	Occasional limestone		4	SS	50/0.150		156		○		
			5	SS	50/0.125		155		○		
			6	SS	50/0.125		154		○		
152.1			7	SS	50/		153		○		
7.7	END OF BOREHOLE AT 7.7m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.2m, THEN ASPHALT TO SURFACE.				0.125						

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE
10

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Appendix B

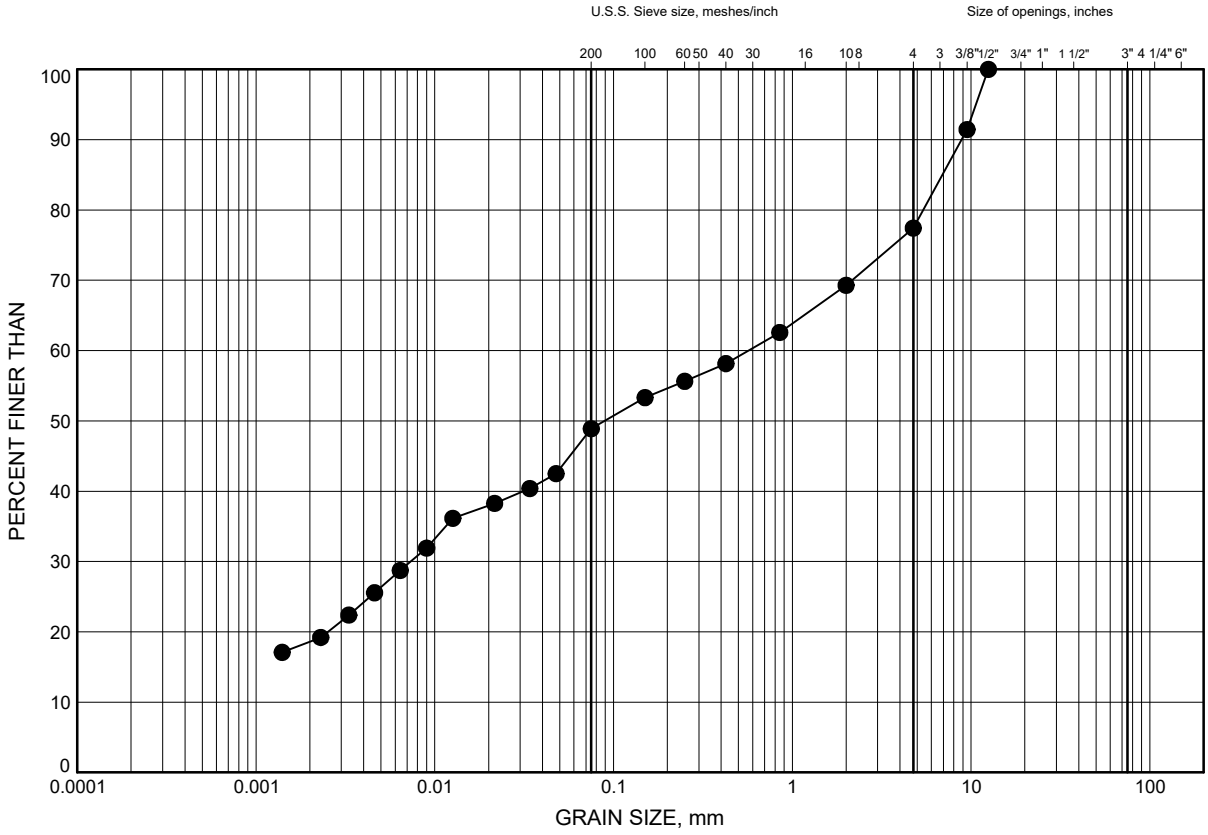
Laboratory Test Results

HWY 401 EBL Basketweave Structure

GRAIN SIZE DISTRIBUTION

FIGURE B1

Gravelly SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BW 16-09	0.38	159.42

Date December 2016

GWP# 2147-10-00

THURBER

Prep'd AN

Chkd. SKP

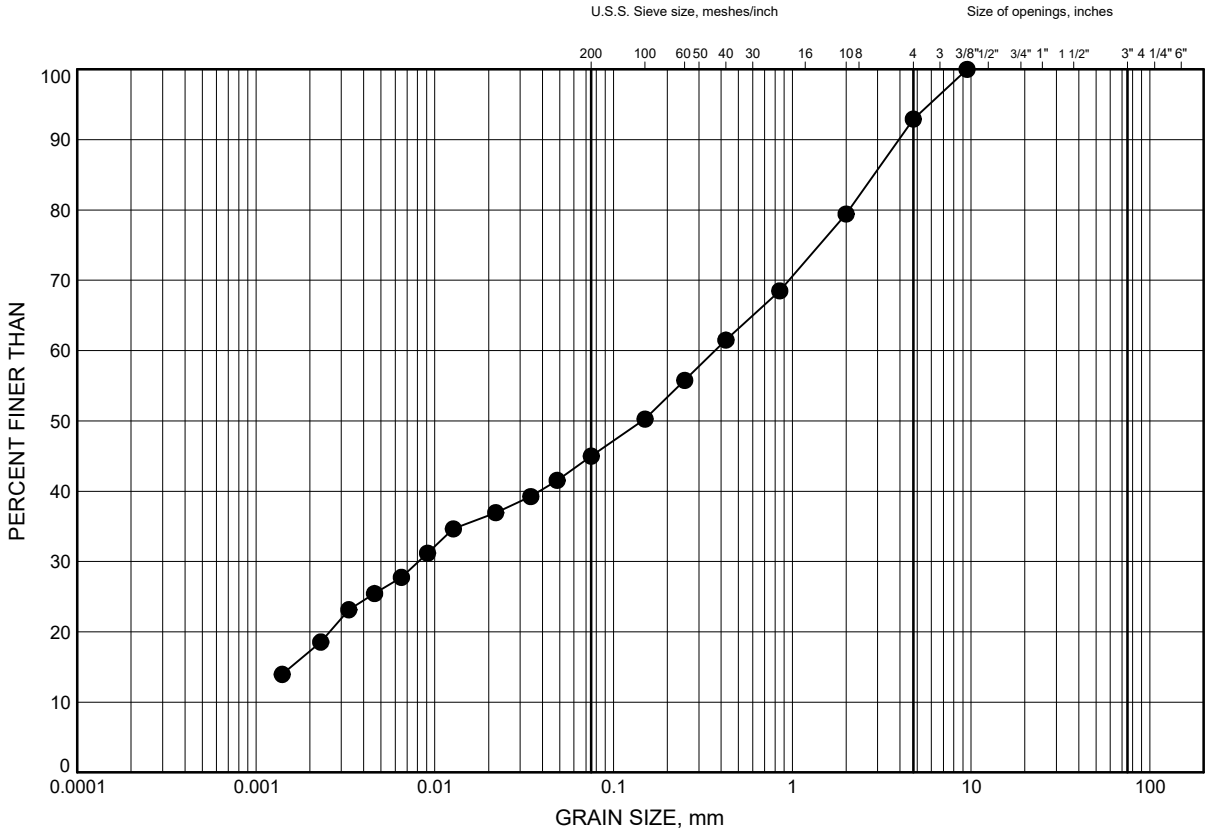
GRAIN SIZE DISTRIBUTION - THURBER MTO-12669.GPJ 12/1/16

HWY 401 EBL Basketweave Structure

GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BW 16-01	1.07	160.53

GRAIN SIZE DISTRIBUTION - THURBER MTO-12669.GPJ 12/1/16

Date December 2016

GWP# 2147-10-00

THURBER

Prep'd AN

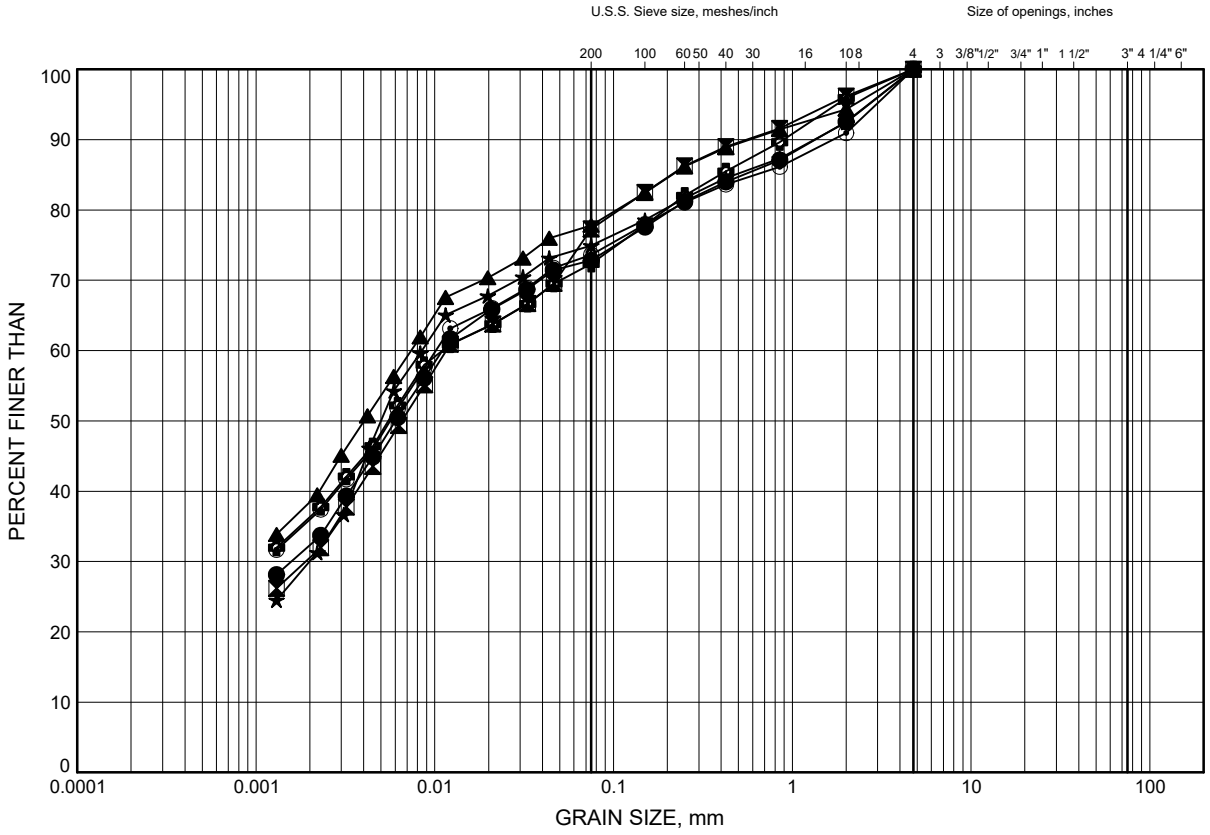
Chkd. SKP

HWY 401 EBL Basketweave Structure

GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty CLAY FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BW 16-01	2.51	159.09
⊠	BW 16-02	2.51	158.19
▲	BW 16-03	3.28	161.02
★	BW 16-04	1.75	157.85
⊙	BW 16-05	0.99	159.11
✿	BW 16-07	0.99	157.71

Date December 2016

GWP# 2147-10-00

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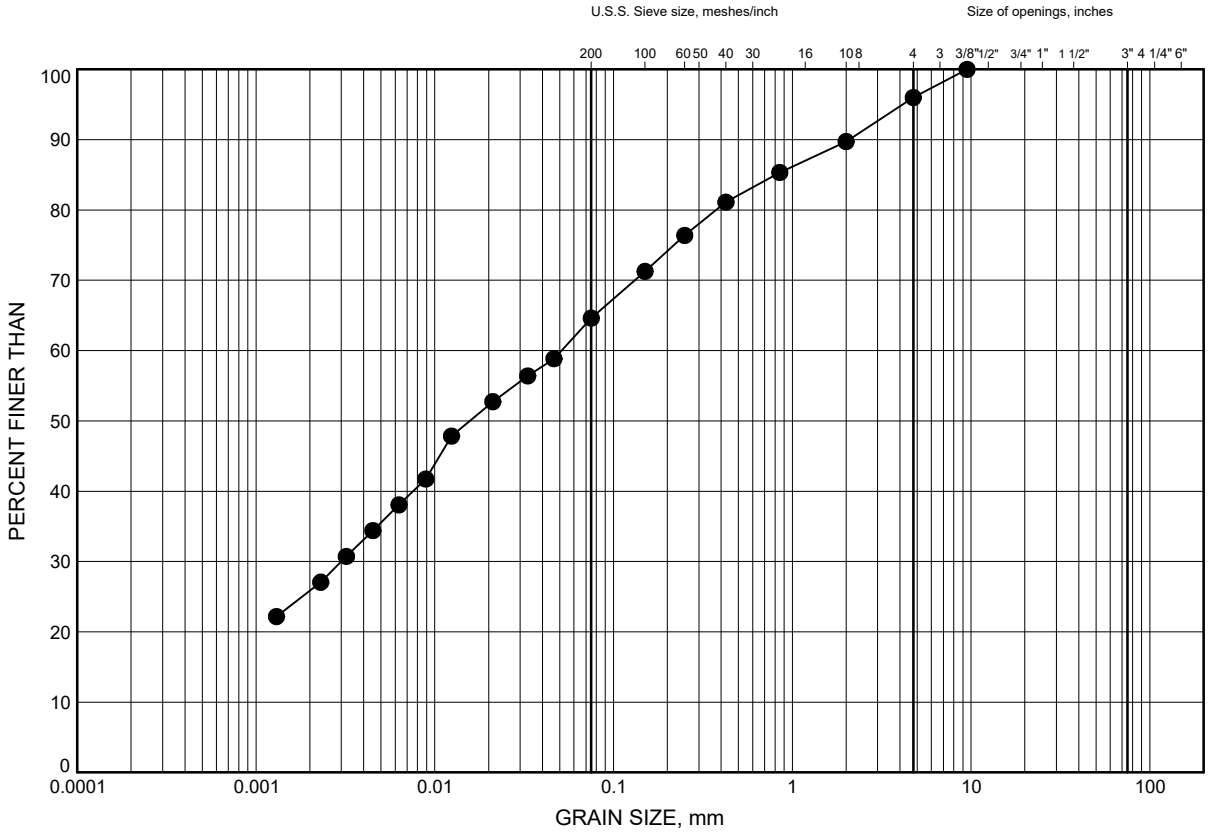
GRAIN SIZE DISTRIBUTION - THURBER MTO-12669.GPJ 12/1/16

HWY 401 EBL Basketweave Structure

GRAIN SIZE DISTRIBUTION

FIGURE B4

Silty CLAY FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BW 16-08	4.80	159.30

Date December 2016

GWP# 2147-10-00

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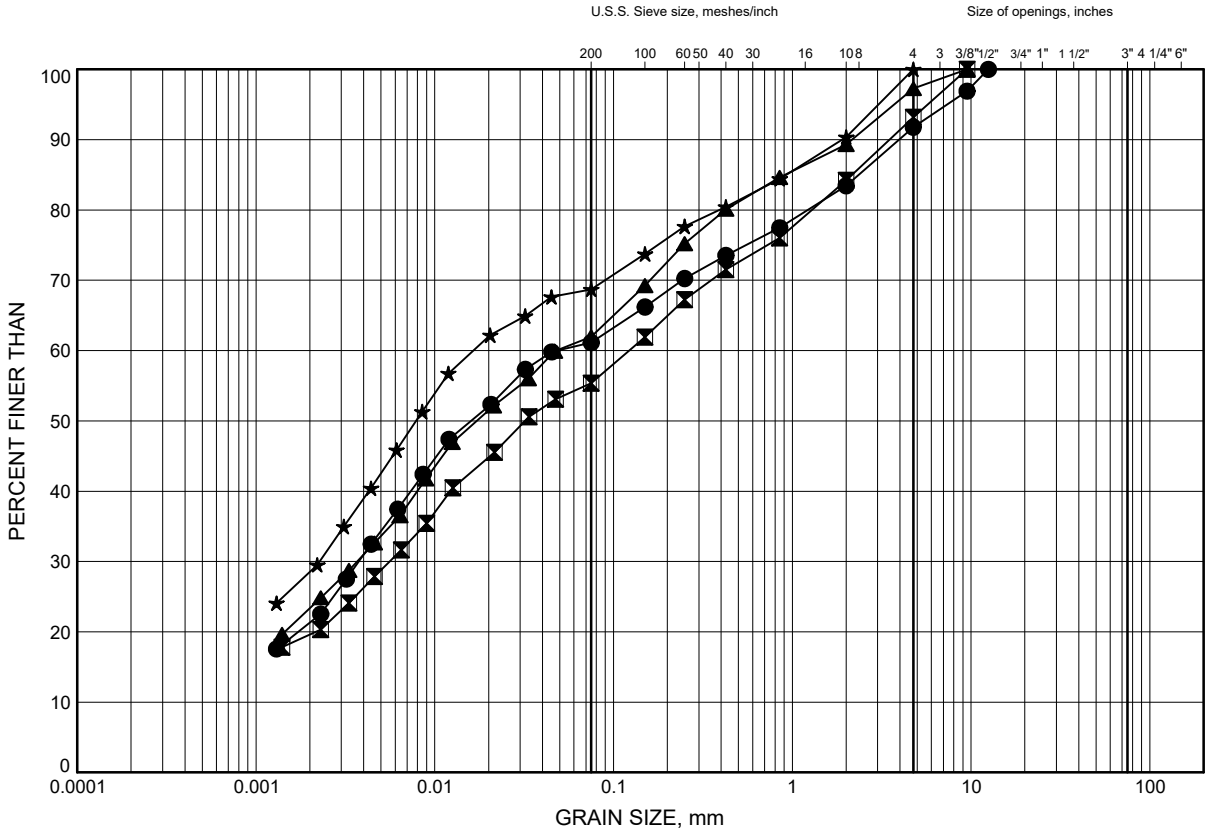
GRAIN SIZE DISTRIBUTION - THURBER MTO-12669.GPJ 12/1/16

HWY 401 EBL Basketweave Structure

GRAIN SIZE DISTRIBUTION

FIGURE B5

Silty CLAY TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BW 16-01	7.85	153.75
⊠	BW 16-02	4.80	155.90
▲	BW 16-03	7.64	156.66
★	BW 16-05	2.59	157.51

Date December 2016

GWP# 2147-10-00

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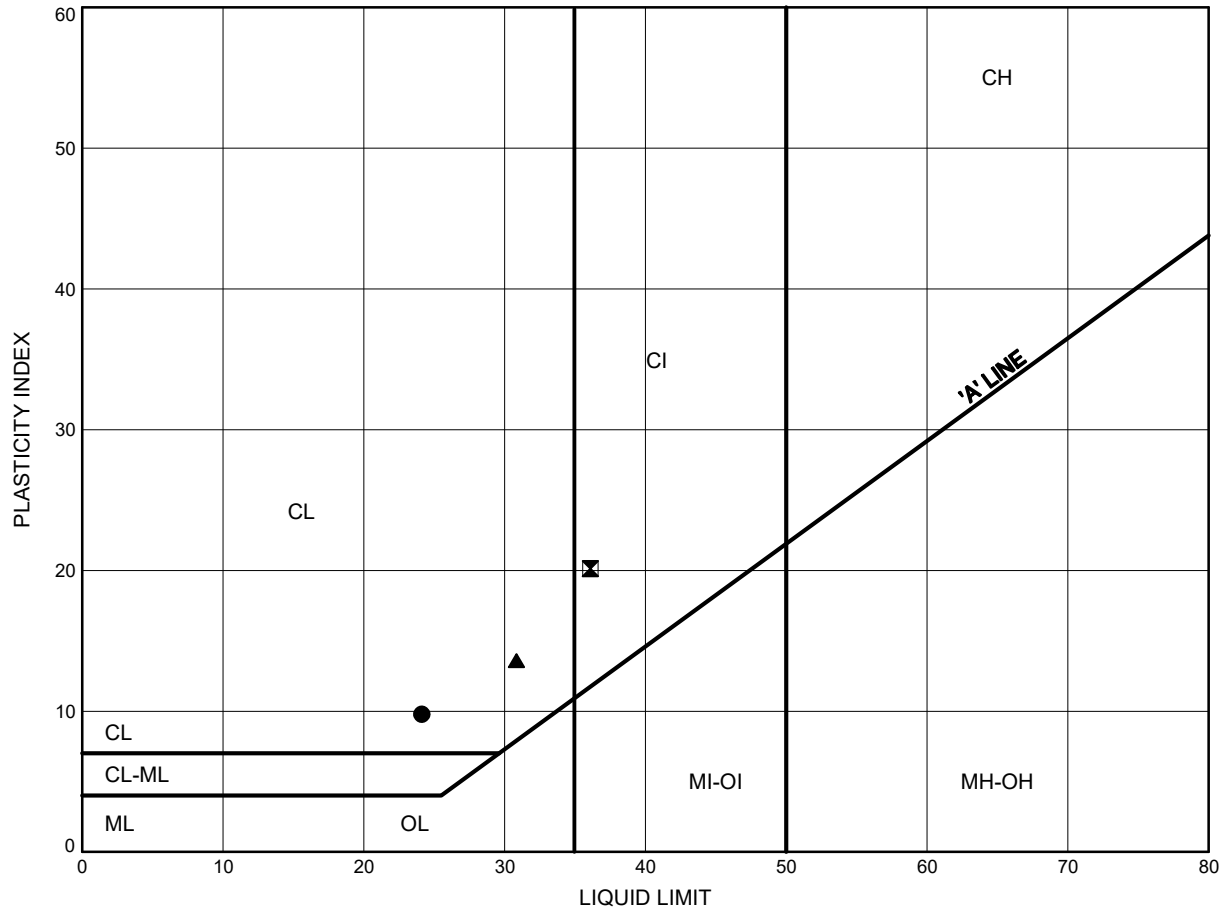
GRAIN SIZE DISTRIBUTION - THURBER MTO-12669.GPJ 12/1/16

HWY 401 EBL Basketweave Structure

ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Silty CLAY FILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BW 16-04	2.51	157.09
⊠	BW 16-06	0.99	158.01
▲	BW 16-08	3.28	160.82

Date December 2016

GWP# 2147-10-00

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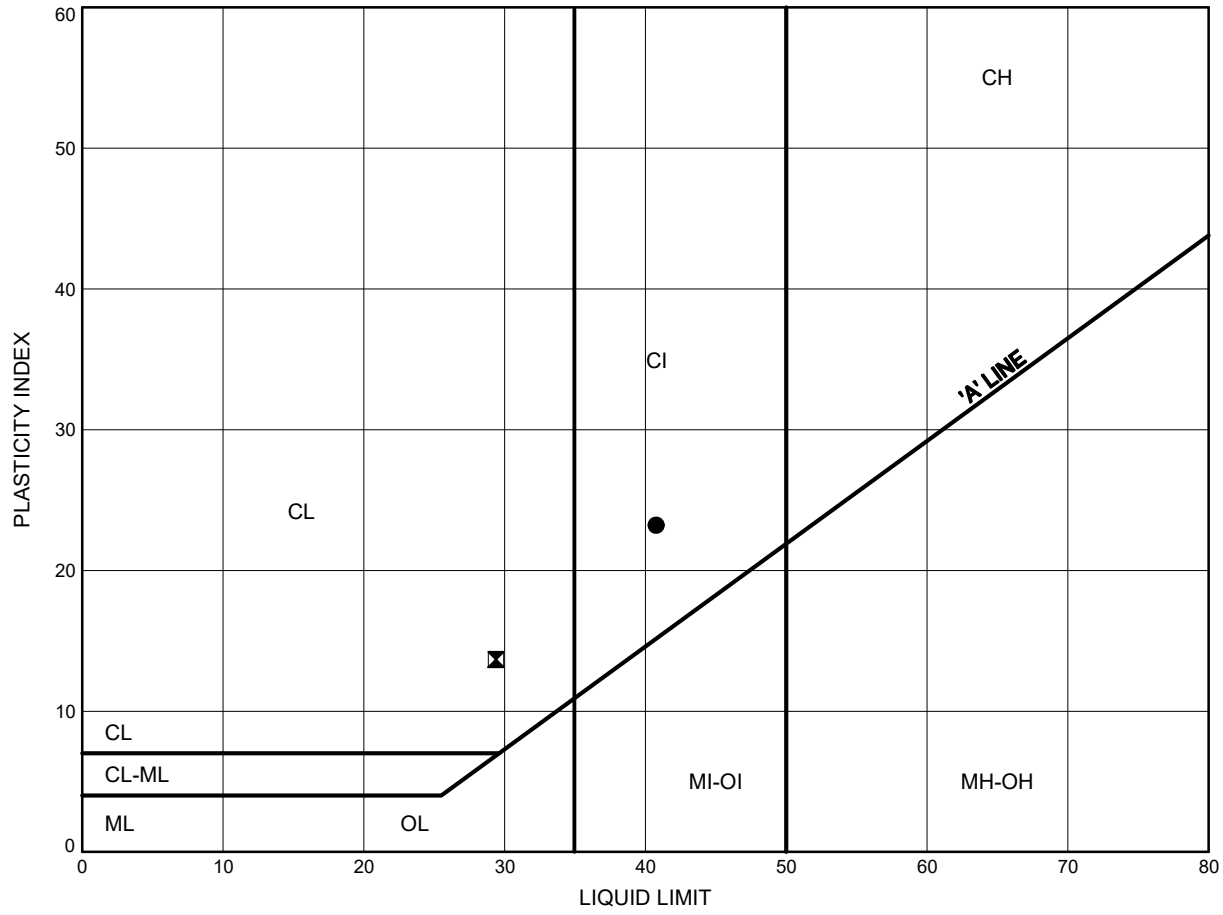
THURBALT MTO-12669.GPJ 12/1/16

HWY 401 EBL Basketweave Structure

ATTERBERG LIMITS TEST RESULTS

FIGURE B7

Silty CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BW 16-01	6.32	155.28
⧓	BW 16-03	6.32	157.98

Date December 2016

GWP# 2147-10-00

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Chkd. SKP

THURBALT MTO-12669.GPJ 12/1/16

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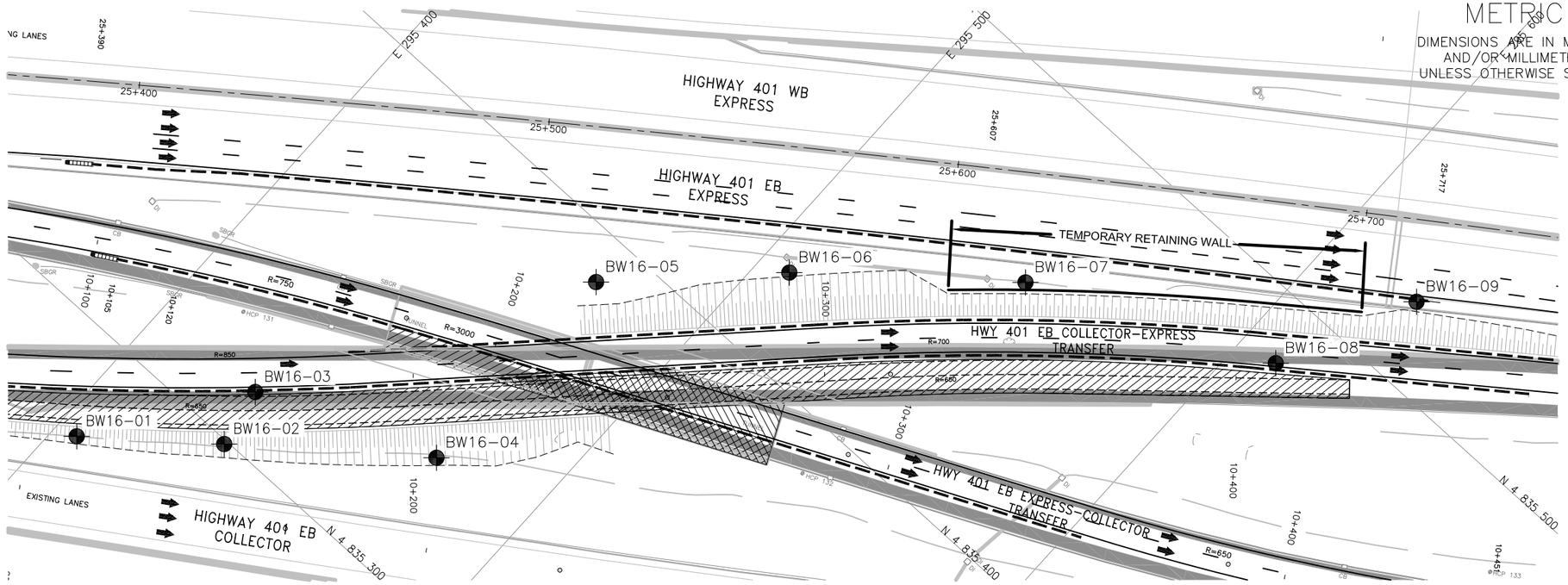
Appendix C

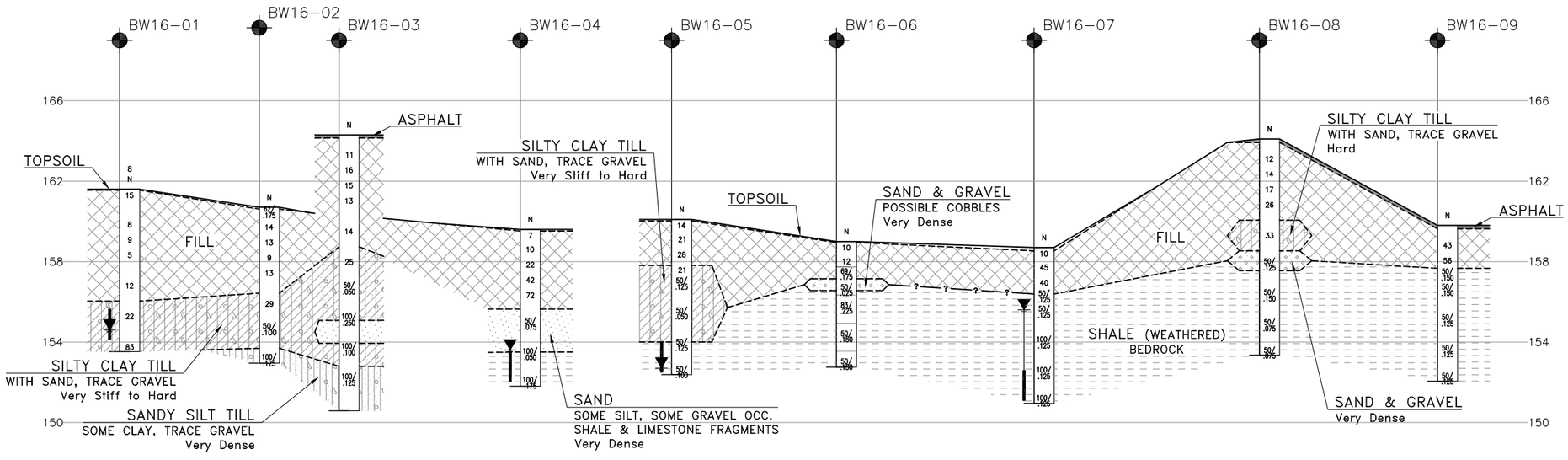
Drawings titled “Borehole Locations and Soil Strata”

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN



PLAN
25 0 25 50m



PROFILE ALONG ℄ HWY 401 COLLECTOR-EXPRESS TRANSFER
25 0 25 50m H
5 0 5 10 V

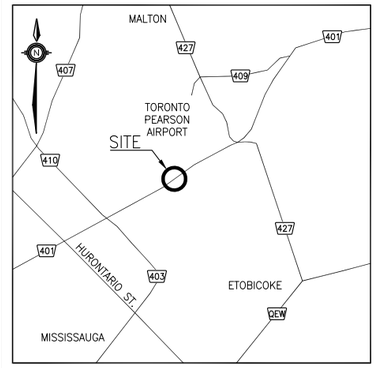
CONT No
WP No 2147-10-00

HIGHWAY 401 EBL
COLLECTOR TO EXPRESS TRANSFER
BASKETWEAVE STRUCTURE
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

AECOM

THURBER ENGINEERING LTD.



KEYPLAN

	LEGEND
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
BW16-01	161.6	4 835 276.5	295 405.3
BW16-02	160.7	4 835 299.1	295 433.2
BW16-03	164.3	4 835 313.6	295 430.3
BW16-04	159.6	4 835 331.2	295 473.8
BW16-05	160.1	4 835 388.9	295 474.0
BW16-06	159.0	4 835 422.1	295 507.3
BW16-07	158.7	4 835 458.7	295 551.6
BW16-08	164.1	4 835 484.9	295 609.9
BW16-09	159.8	4 835 518.9	295 625.3

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No.

REVISIONS		
DATE	BY	DESCRIPTION

DESIGN	SKP	CHK	CODE	LOAD	DATE DEC 2016
DRAWN	AN	CHK SKP	SITE	STRUCT	DWG 1

FILENAME: H:\Drafting\12000\12669_TED12669-BHPP-Basketweave.dwg
PLOTDATE: 12/1/2016 9:58 AM

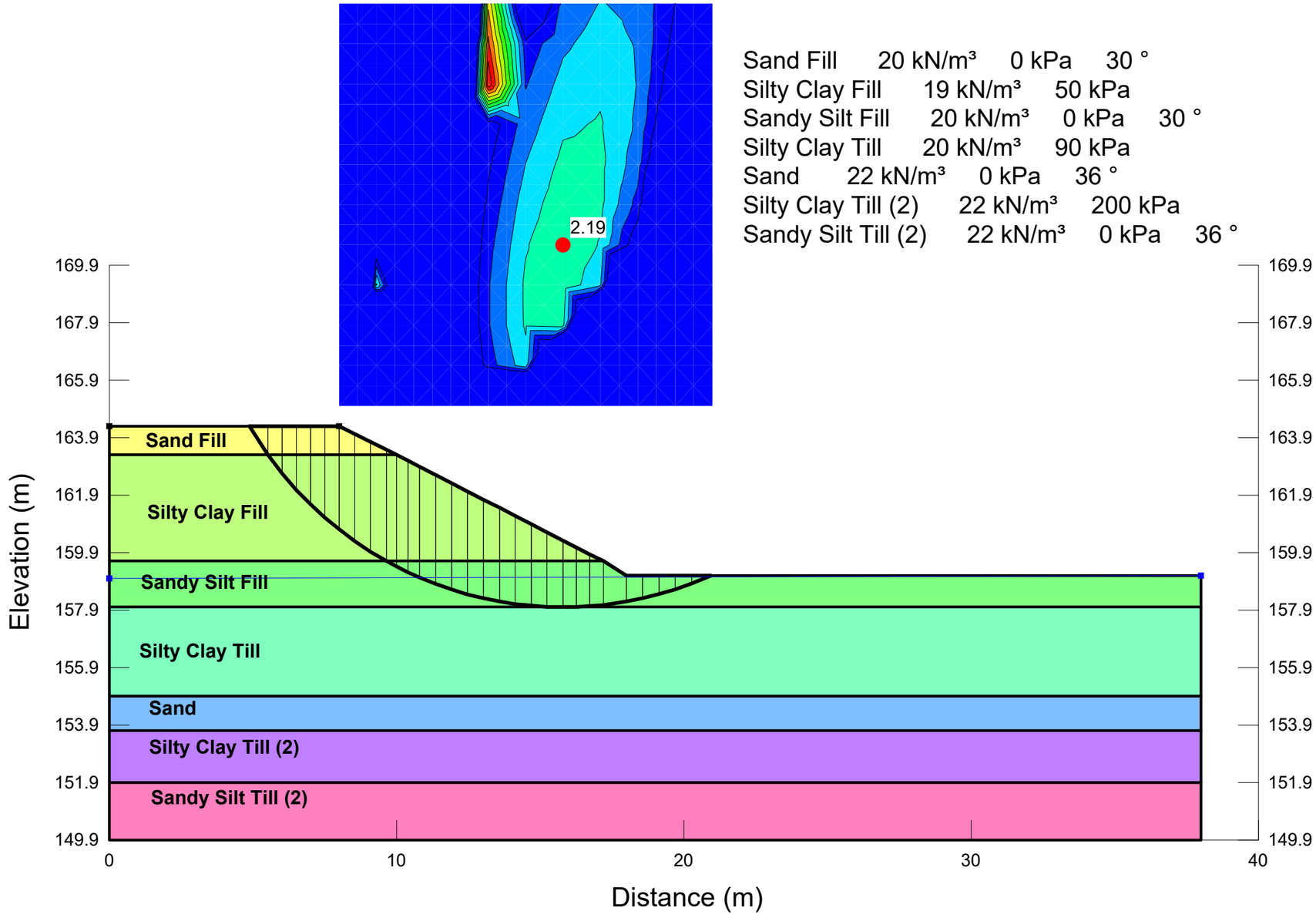
THURBER

Appendix D

Selected Slope Stability Analyses Results

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+170 BEFORE WIDENING [UNDRAINED]

FIGURE D1



Sand Fill	20 kN/m³	0 kPa	30 °
Silty Clay Fill	19 kN/m³	50 kPa	
Sandy Silt Fill	20 kN/m³	0 kPa	30 °
Silty Clay Till	20 kN/m³	90 kPa	
Sand	22 kN/m³	0 kPa	36 °
Silty Clay Till (2)	22 kN/m³	200 kPa	
Sandy Silt Till (2)	22 kN/m³	0 kPa	36 °

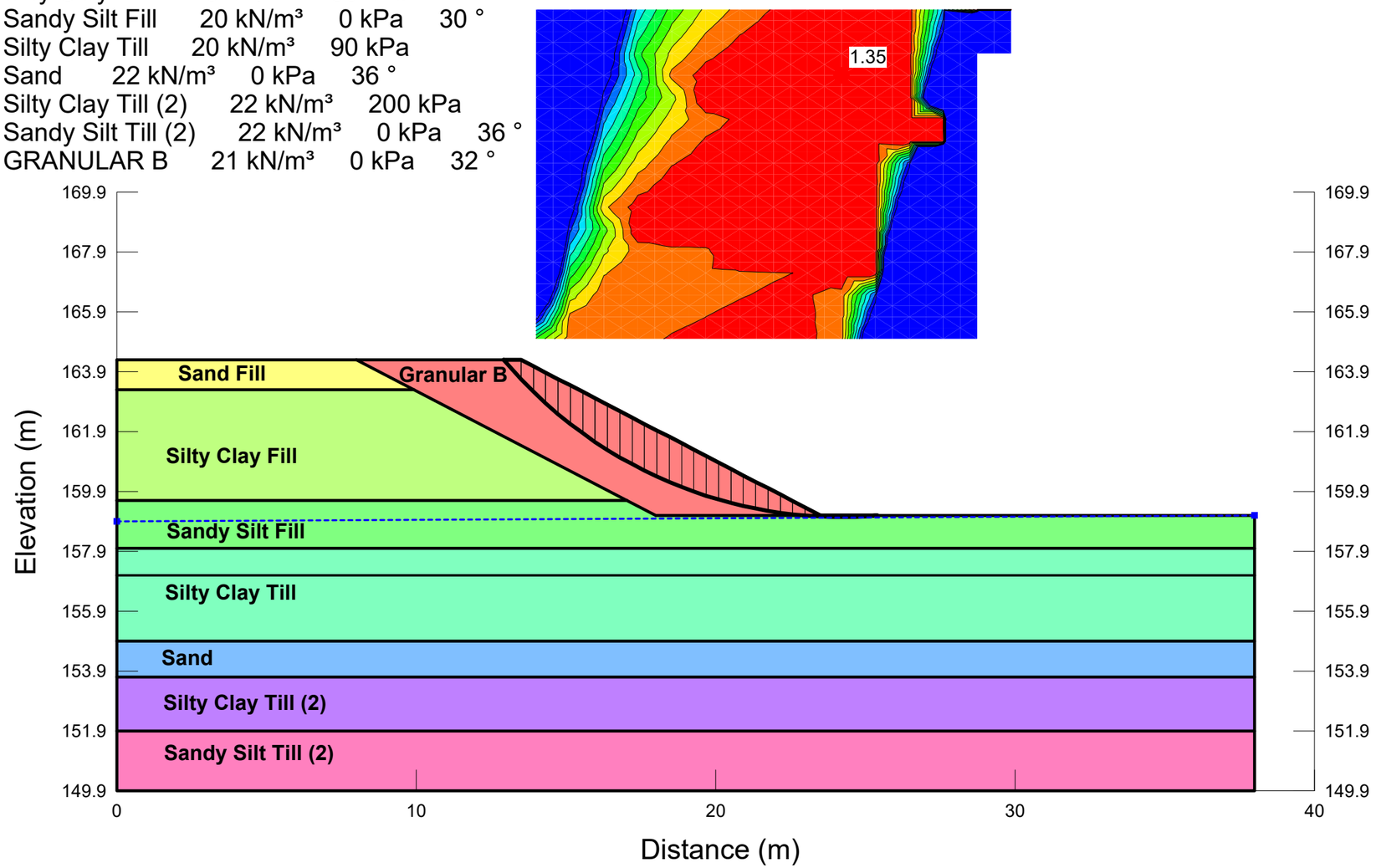
Date: December 2016
File No.: 12669

Analysis By: MSH
Reviewed By: SKP

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+170 AFTER WIDENING [UNDRAINED]

FIGURE D2

Sand Fill 20 kN/m³ 0 kPa 30 °
Silty Clay Fill 19 kN/m³ 50 kPa
Sandy Silt Fill 20 kN/m³ 0 kPa 30 °
Silty Clay Till 20 kN/m³ 90 kPa
Sand 22 kN/m³ 0 kPa 36 °
Silty Clay Till (2) 22 kN/m³ 200 kPa
Sandy Silt Till (2) 22 kN/m³ 0 kPa 36 °
GRANULAR B 21 kN/m³ 0 kPa 32 °

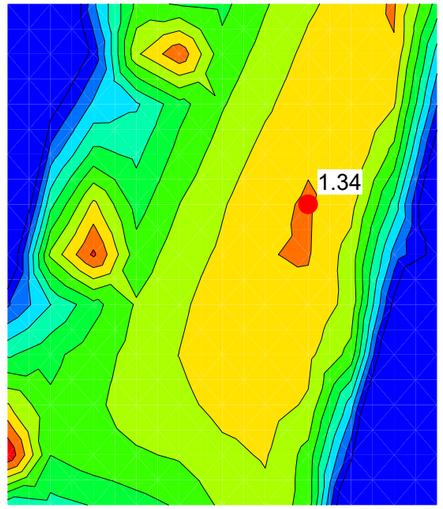


Date: December 2016
File No.: 12669

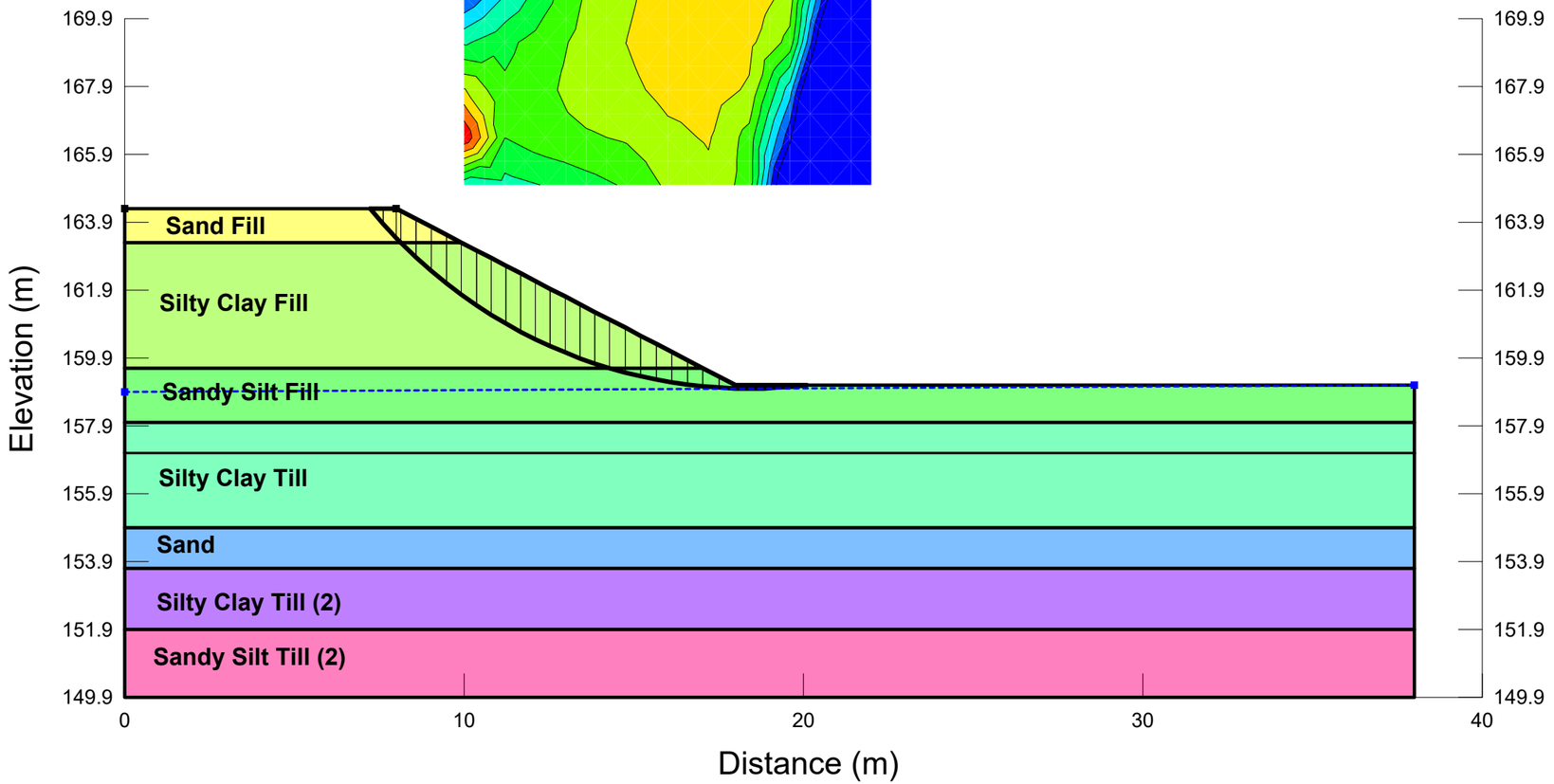
Analysis By: MSH
Reviewed By: SKP

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+170 BEFORE WIDENING [DRAINED]

FIGURE D3



Sand Fill	20 kN/m³	0 kPa	30 °
Silty Clay Fill	19 kN/m³	2 kPa	28 °
Sandy Silt Fill	20 kN/m³	0 kPa	30 °
Silty Clay Till	20 kN/m³	0 kPa	32 °
Sand	22 kN/m³	0 kPa	36 °
Silty Clay Till (2)	22 kN/m³	0 kPa	34 °
Sandy Silt Till (2)	22 kN/m³	0 kPa	36 °



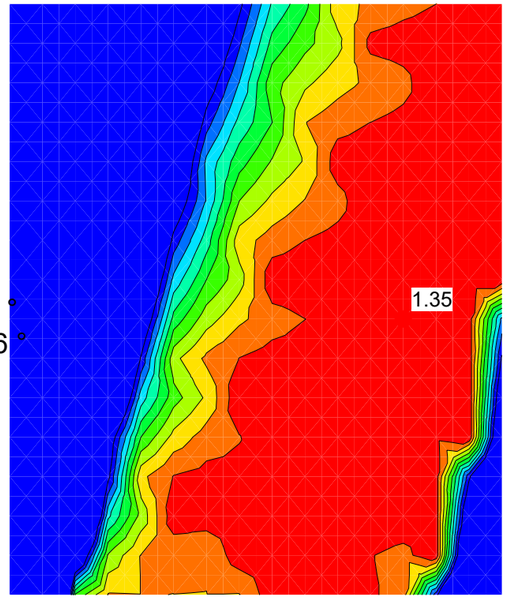
Date: December 2016
File No.: 12669

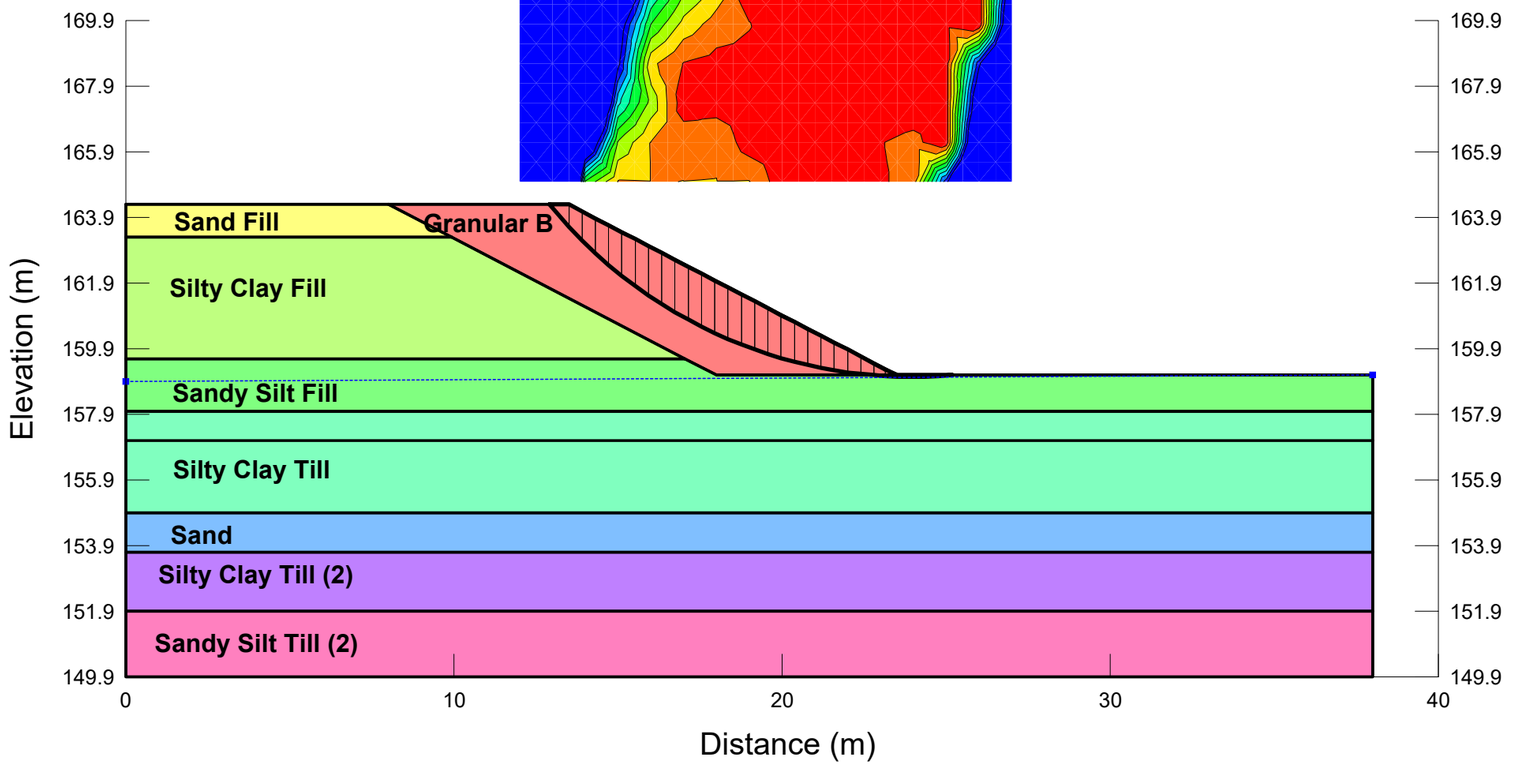
Analysis By: MSH
Reviewed By: SKP

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+170 AFTER WIDENING [DRAINED]

FIGURE D4

Sand Fill	20 kN/m³	0 kPa	30 °
Silty Clay Fill	19 kN/m³	0 kPa	28 °
Sandy Silt Fill	20 kN/m³	0 kPa	30 °
Silty Clay Till	20 kN/m³	0 kPa	32 °
Sand	22 kN/m³	0 kPa	36 °
Silty Clay Till (2)	22 kN/m³	0 kPa	34 °
Sandy Silt Till (2)	22 kN/m³	0 kPa	36 °
GRANULAR B	21 kN/m³	0 kPa	32 °





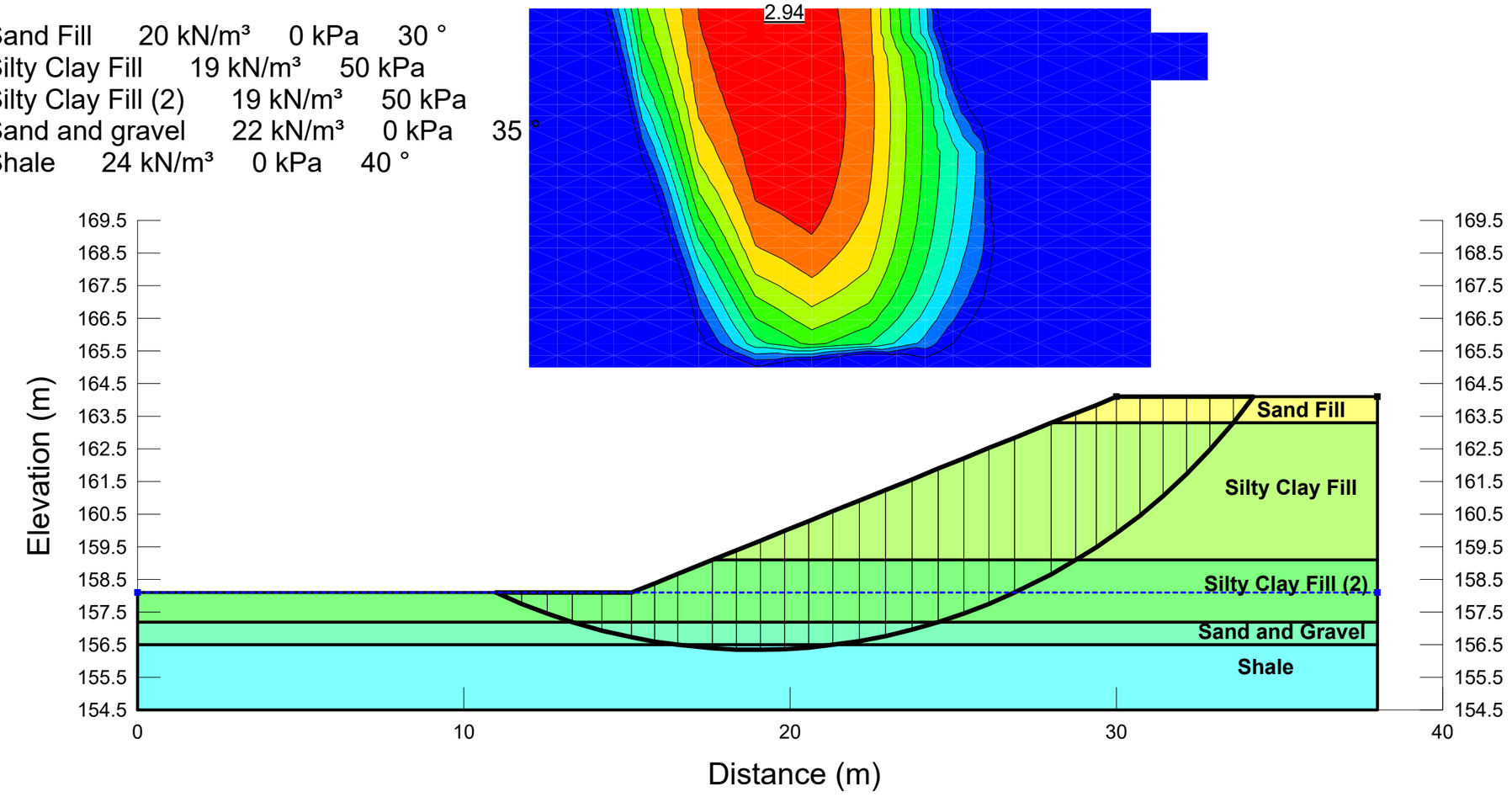
Date: December 2016
File No.: 12669

Analysis By: MSH
Reviewed By: SKP

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+290 BEFORE WIDENING [UNDRAINED]

FIGURE D5

Sand Fill 20 kN/m³ 0 kPa 30 °
Silty Clay Fill 19 kN/m³ 50 kPa
Silty Clay Fill (2) 19 kN/m³ 50 kPa
Sand and gravel 22 kN/m³ 0 kPa 35 °
Shale 24 kN/m³ 0 kPa 40 °



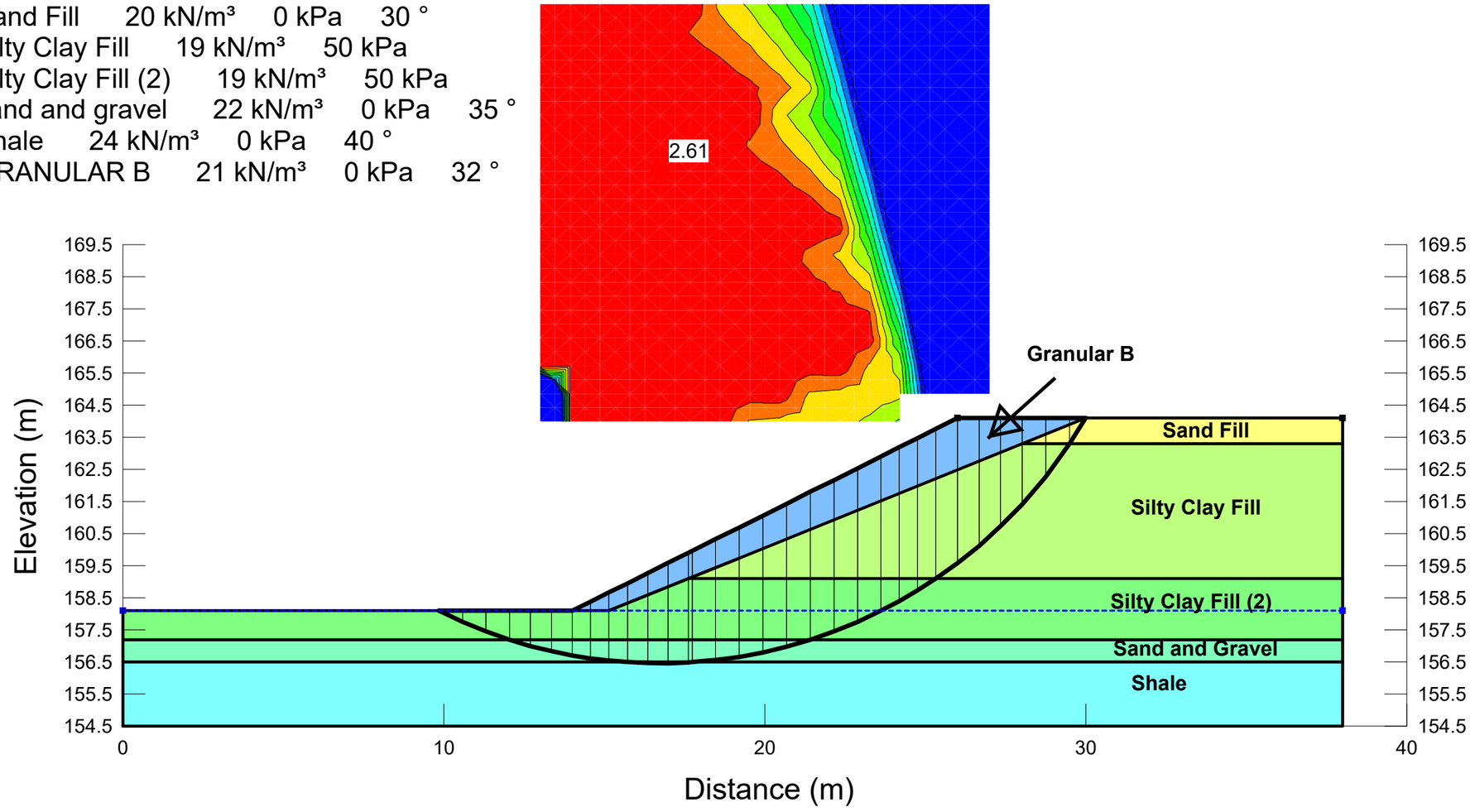
Date: December 2016
File No.: 12669

Analysis By: MSH
Reviewed By: SKP

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+290 AFTER WIDENING [UNDRAINED]

FIGURE D6

Sand Fill 20 kN/m³ 0 kPa 30 °
Silty Clay Fill 19 kN/m³ 50 kPa
Silty Clay Fill (2) 19 kN/m³ 50 kPa
sand and gravel 22 kN/m³ 0 kPa 35 °
Shale 24 kN/m³ 0 kPa 40 °
GRANULAR B 21 kN/m³ 0 kPa 32 °



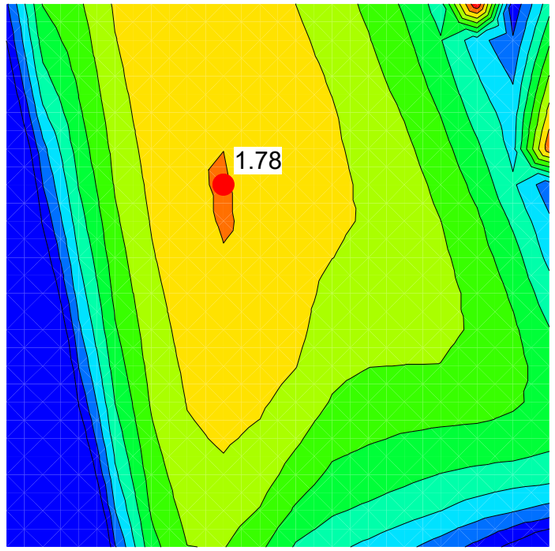
Date: December 2016
File No.: 12669

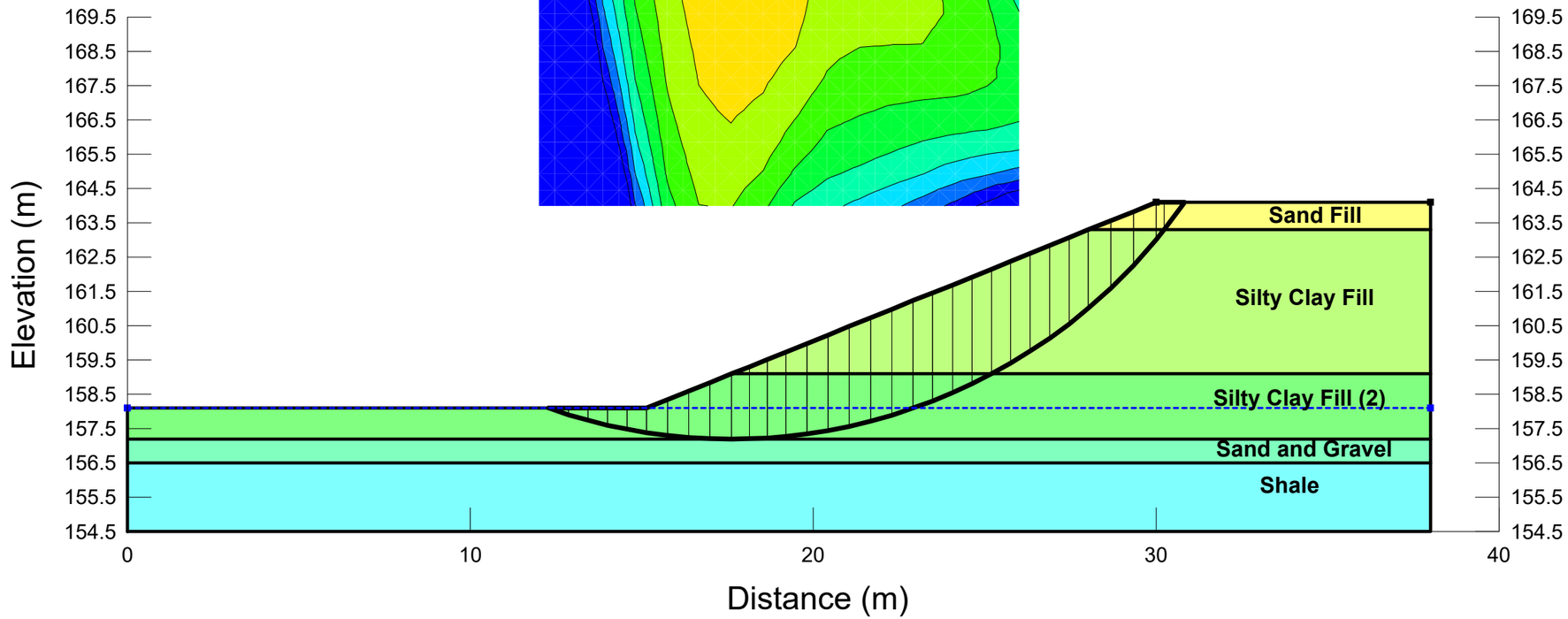
Analysis By: MSH
Reviewed By: SKP

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+290 BEFORE WIDENING [DRAINED]

FIGURE D7

Sand Fill	20 kN/m³	0 kPa	30 °
Silty Clay Fill	19 kN/m³	2 kPa	30 °
Silty Clay Fill (2)	19 kN/m³	2 kPa	30 °
Sand and gravel	22 kN/m³	0 kPa	35 °
Shale	24 kN/m³	0 kPa	40 °





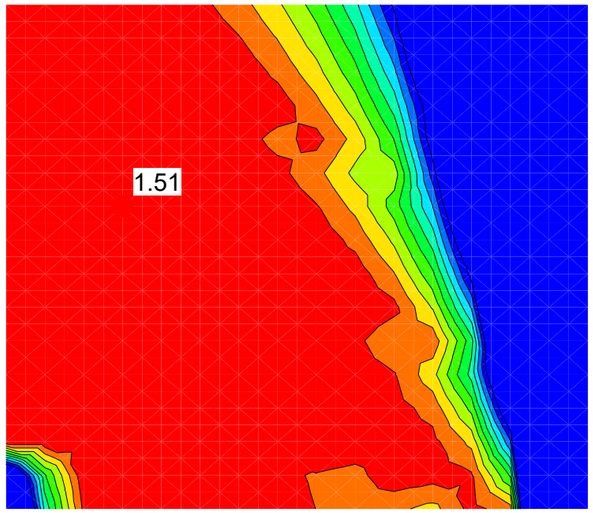
Date: December 2016
File No.: 12669

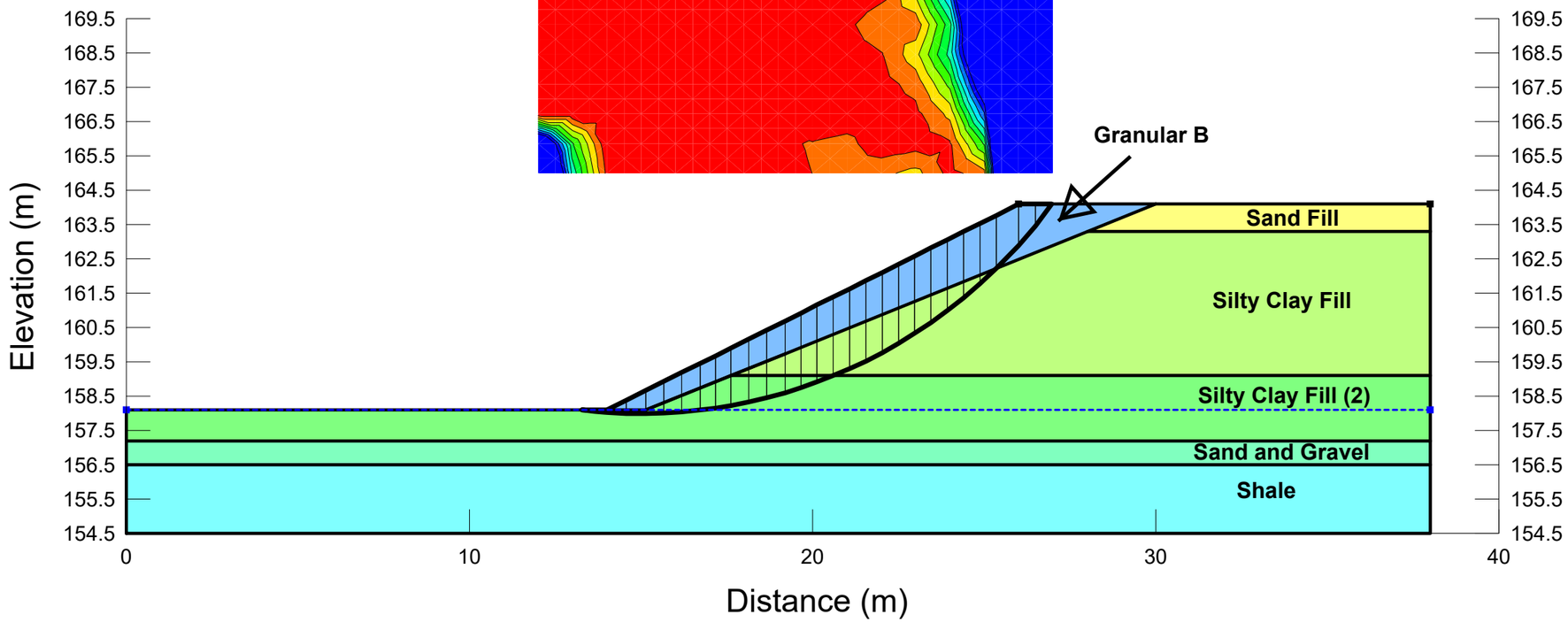
Analysis By: MSH
Reviewed By: SKP

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+290 AFTER WIDENING [DRAINED]

FIGURE D8

Sand Fill 20 kN/m³ 0 kPa 30 °
Silty Clay Fill 19 kN/m³ 2 kPa 30 °
Silty Clay Fill (2) 19 kN/m³ 2 kPa 30 °
sand and gravel 22 kN/m³ 0 kPa 35 °
Shale 24 kN/m³ 0 kPa 40 °
GRANULAR B 21 kN/m³ 0 kPa 32 °



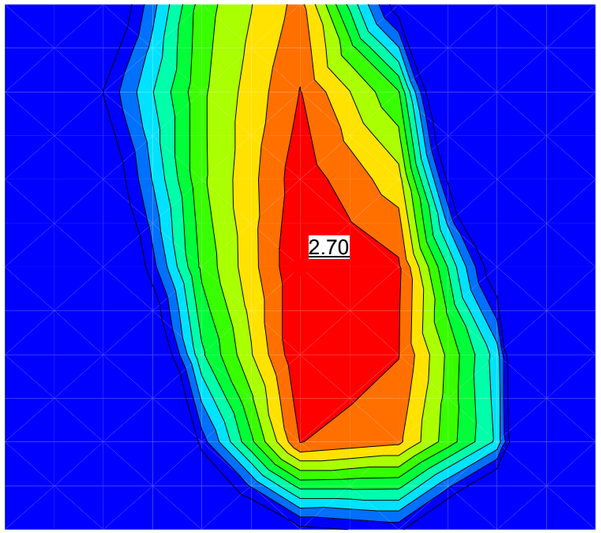


Date: December 2016
File No.: 12669

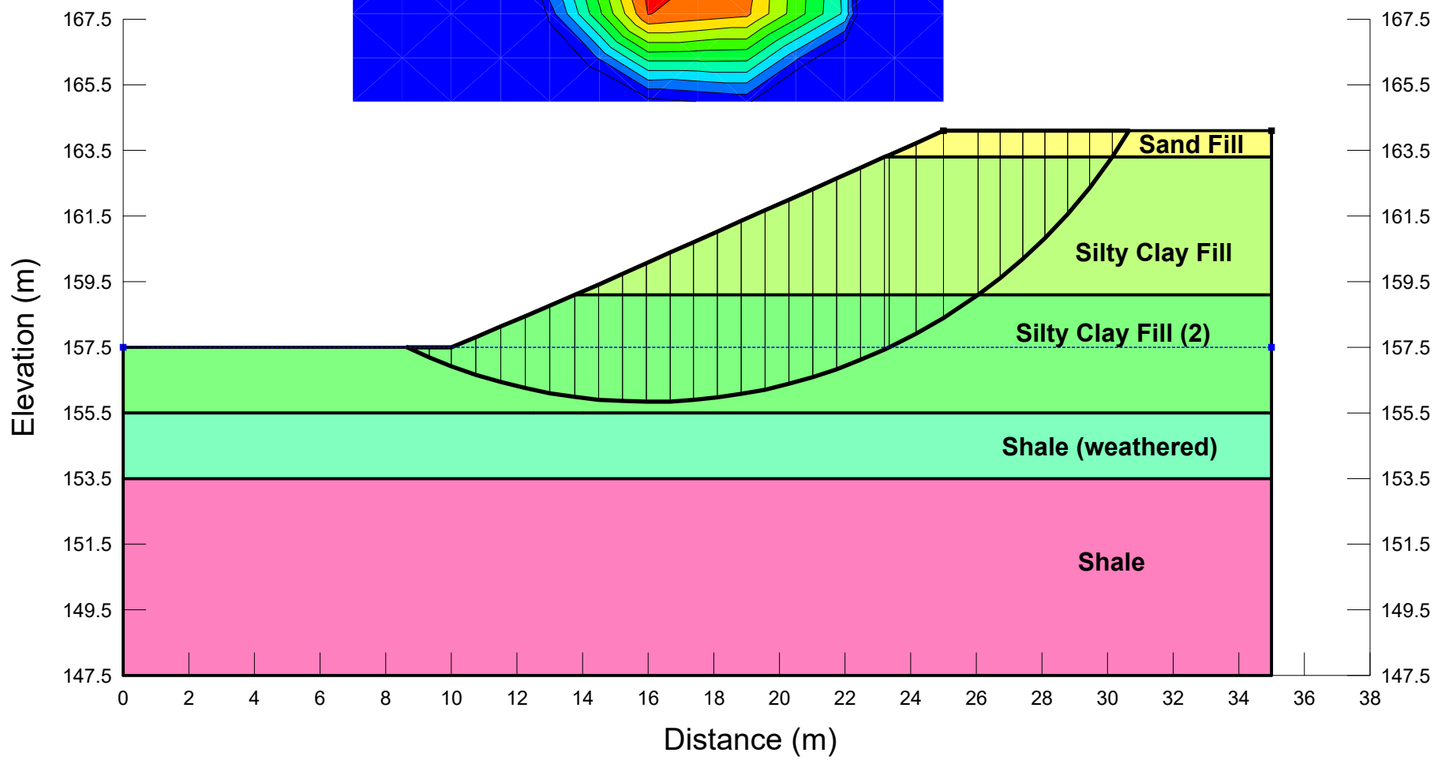
Analysis By: MSH
Reviewed By: SKP

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+340 BEFORE WIDENING [UNDRAINED]

FIGURE D9



Sand Fill 20 kN/m³ 0 kPa 30 °
Silty Clay Fill 19 kN/m³ 50 kPa
Silt Clay Fill 2 21 kN/m³ 50 kPa
shale (weathered) 24 kN/m³ 0 kPa 40 °
Shale

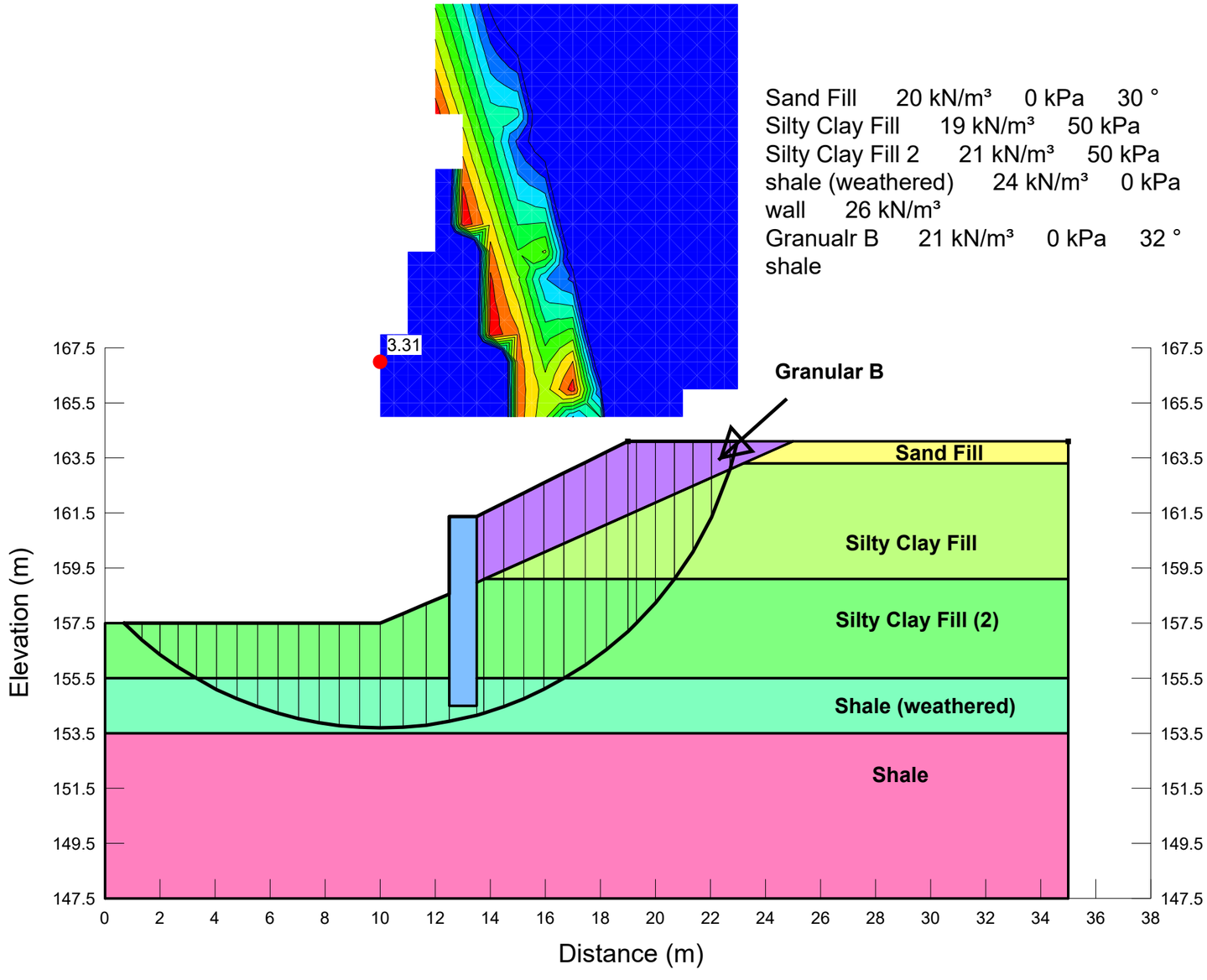


Date: December 2016
File No.: 12669

Analysis By: MSH
Reviewed By: SKP

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+340 AFTER WIDENING [UNDRAINED]

FIGURE D10



Sand Fill 20 kN/m³ 0 kPa 30 °
Silty Clay Fill 19 kN/m³ 50 kPa
Silty Clay Fill 2 21 kN/m³ 50 kPa
shale (weathered) 24 kN/m³ 0 kPa 40 °
wall 26 kN/m³
Granualr B 21 kN/m³ 0 kPa 32 °
shale

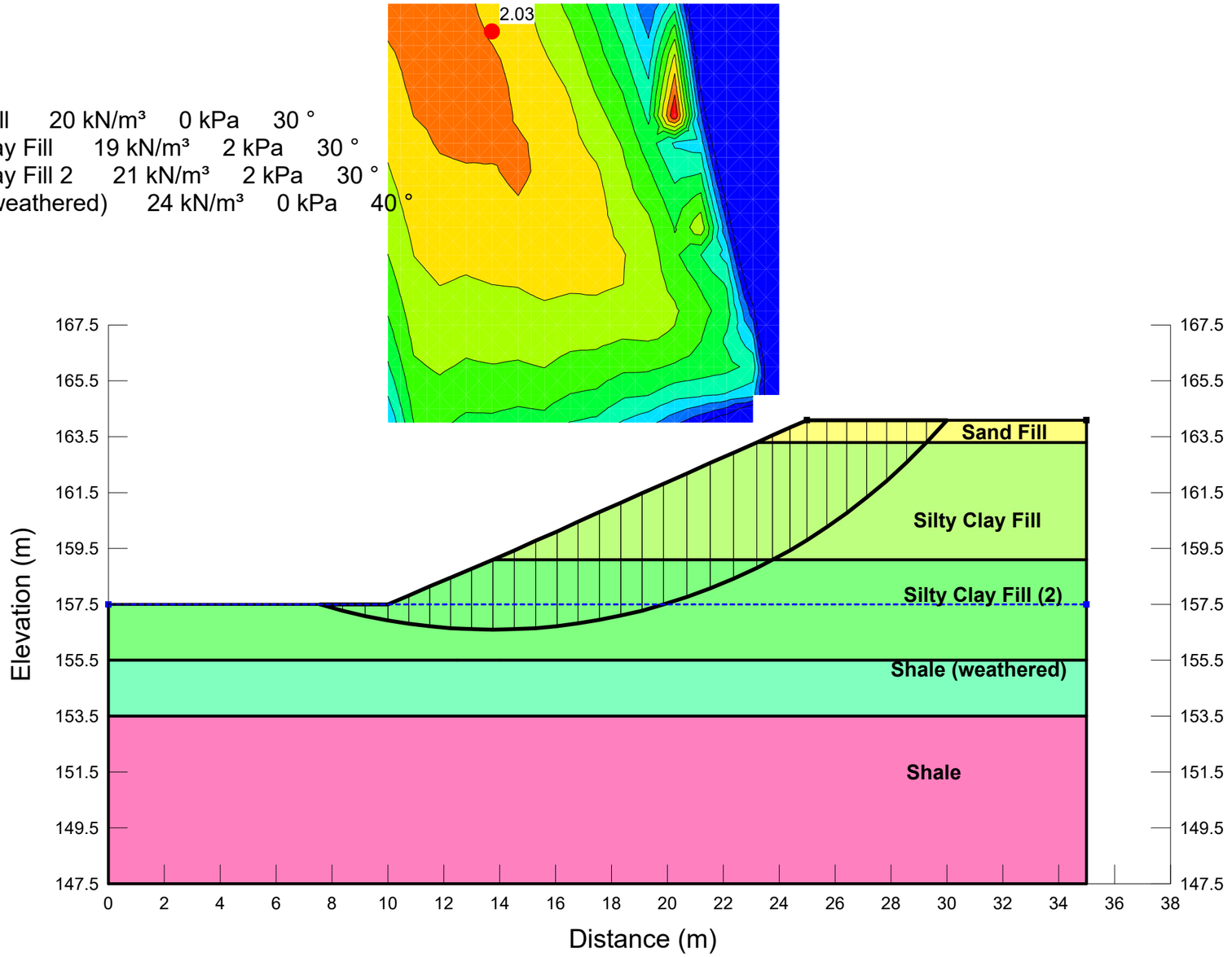
Date: December 2016
File No.: 12669

Analysis By: MSH
Reviewed By: SKP

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+340 BEFORE WIDENING [DRAINED]

FIGURE D11

Sand Fill 20 kN/m³ 0 kPa 30 °
Silty Clay Fill 19 kN/m³ 2 kPa 30 °
Silty Clay Fill 2 21 kN/m³ 2 kPa 30 °
shale (weathered) 24 kN/m³ 0 kPa 40 °
shale



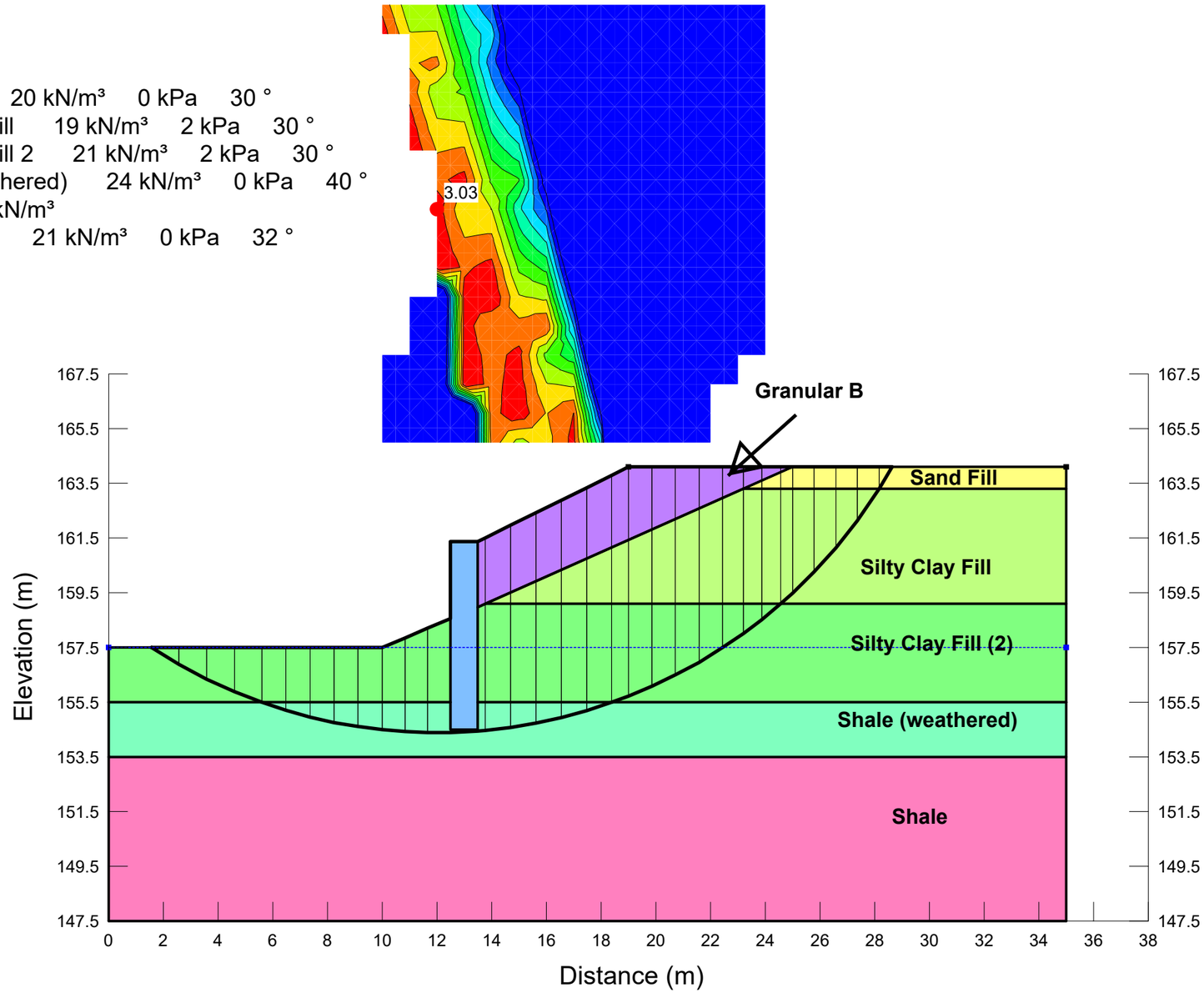
Date: December 2016
File No.: 12669

Analysis By: MSH
Reviewed By: SKP

WIDENING OF EASTBOUND TRANSFER
HWY 401 BASKETWEAVE
STA. 10+340 AFTER WIDENING [DRAINED]

FIGURE D12

Sand Fill 20 kN/m³ 0 kPa 30 °
Silty Clay Fill 19 kN/m³ 2 kPa 30 °
Silty Clay Fill 2 21 kN/m³ 2 kPa 30 °
shale (weathered) 24 kN/m³ 0 kPa 40 °
wall 26 kN/m³
Granualr B 21 kN/m³ 0 kPa 32 °
Shale



Date: December 2016
File No.: 12669

Analysis By: MSH
Reviewed By: SKP

THURBER

Appendix E

List of OPSS and Suggested Wordings for NSSPs

Client: AECOM Date: December 1, 2016
File No.: 12669
E file: H:\12000-12999\12669 Hwy 401 403 410 Contract 2\Reports & Memos\Basketweave\12669 401 basketweave rep draft FIDR nov 16.docx

1. List of OPSS Documents Referenced in this Report

- OPSS.PROV 903
- OPSS.PROV 206
- OPSS.PROV 804
- OPSS.PROV 501
- OPSS.PROV 539
- OPSS 902
- OPSS.PROV 1010
- OPSD 3102.100
- OPSD 208.010

2. Suggested Text for NSSP on "Temporary Retaining Wall Design and Installation"

Given that the temporary retaining wall is to be used for retention of the Highway 401 embankment, it is recommended that Performance Level 1b as per Clause 539.04.01.01, corresponding to a maximum permissible ground movement of 10 mm, be assigned for this wall as per OPSS.PROV 539 "Protection System". This requirement is specified to minimize ground movements adjacent to the Highway 401 travelled lanes.

The design of this temporary retaining wall/roadway protection should be the responsibility of the Contractor. A continuous interlocking sheetpile system or a soldier pile and lagging system with closely spaced piles may be considered. It is anticipated that both the sheetpiles and the soldier piles will need to be extended through the existing silty clay embankment fill to reach the weathered shale to provide the required toe resistance. Pre-augering will be required to socket the soldier piles or the sheetpiles into the weathered shale.

In order for a soldier pile and lagging wall to be suitable for use as a temporary wall to retain the Highway 401 embankment, and to satisfy global stability and limit adjacent ground movement, the piles will have to be spaced more closely than those used in typical shoring walls.

The augered holes will encounter soils containing cobbles, boulders and shale fragments and limestone interbeds to reach the weathered shale. The installation (augering) equipment must be capable of dislodging and removing any obstructions such as cobbles, boulders, shale/limestone slabs and to penetrate very dense/hard layers within the soils. Soil sloughing and water seepage will occur in unsupported holes primarily from the fill and water-bearing sands and silts. Construction of augered piles will require the use of temporary steel liners to support the sidewalls and to provide seepage cut-off where required.

3. Suggested Text for NSSP on "Monitoring during Temporary Wall Installation and Operation"

Potential impact of fill placement and temporary retaining wall construction on the existing pavement surface of Highway 401 should be closely monitored.

- Daily visual inspection of the pavement surface must be carried out in the vicinity of the fill placement and wall construction. If cracks form in the pavement or settlement is observed to occur, these matters must immediately be brought to the attention of the Contract Administrator for determining as to whether remedial action is required. Such action may include temporarily re-paving the affected areas.
- Implement a survey monitoring program to include ground settlement monitoring during installation of roadway protection/temporary retaining wall. The ground adjacent to the retained fills behind the temporary wall should be monitored for potential movement.

The Contractor shall be required to propose a visual and survey monitoring program pertinent to their wall design and to satisfy the above objectives. This proposal shall be submitted to the Contract Administrator and Project Designer for their approval prior to commencing the work.